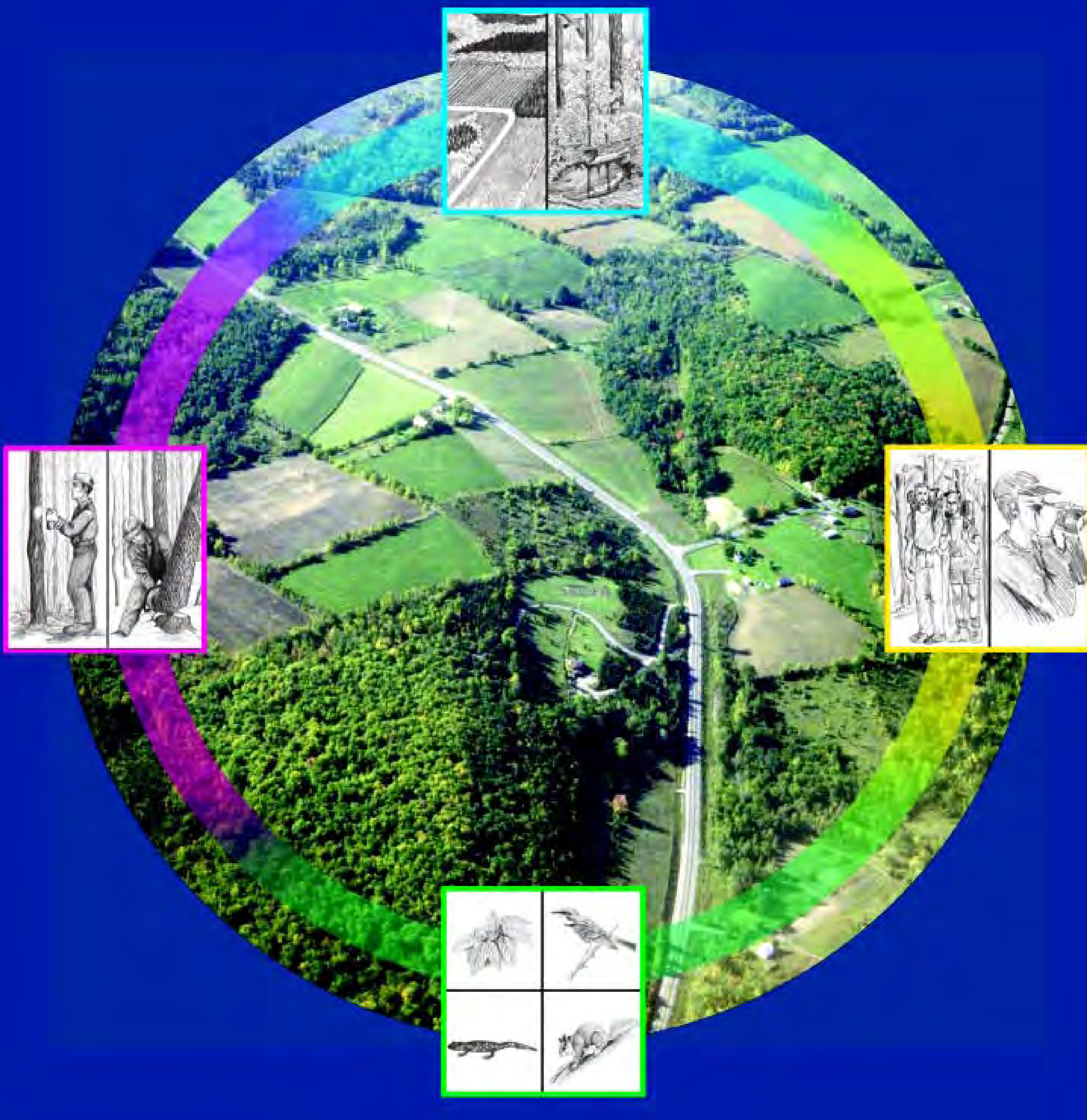
Ontario

A Silvicultural Guide to Managing Southern Ontario Forests



TECHNICAL SERIES

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A Slviculture Guide to Managing Southern Ontario Forests

MNR's Strategic Directions and Statement of Environmental Values

The Ministry of Natural Resources (MNR) is responsible for managing Ontario's natural resources in accordance with the statutes it administers. As the province's lead conservation agency, MNR is the steward of provincial parks, natural heritage areas, forests, fisheries, wildlife, mineral aggregates, fuel minerals and Crown lands and waters that make up 87 per cent of Ontario.

In 1991, the Ministry of Natural Resources released a document entitled *MNR: Direction '90s* which outlined the Ministry's goal and objectives. They are based on the concept of sustainable development, as expressed by the World Commission on Environment and Development. This document was updated in 1994 with a new publication, *Direction '90s…Moving Ahead 1995*. Within MNR, policy and program development take their lead from *Direction '90s* and *Direction 90s…Moving Ahead 1995*. Those strategic directions are also considered in Ministry land use and resource management planning.

In 1994, the MNR finalized its Statement of Environmental Values (SEV) under the Environmental Bill of Rights (EBR). The Ministry's SEV describes how the purposes of the EBR are to be considered whenever decisions that might significantly affect the environment are made in the Ministry. The SEV is based on the goals and objectives of the MNR as described in *Direction '90s* and *Direction '90s…Moving Ahead 1995*, since the strategic direction provided in these documents reflects the purpose of the EBR.

During the development of *A Silvicultural Guide to Managing Southern Ontario Forests*, the Ministry has considered *Direction '90s, Direction '90s…Moving Ahead 1995* and its Statement of Environmental Values. This guide is intended to reflect the directions set out in those documents and to further the objectives of managing our resources on a sustainable basis.

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Notice of Minor Corrections to A Silvicultural Guide to Managing Southern Ontario Forests, OMNR 2000

To update your paper copy of the Guide please download and print the following pages from the updated online version of the Guide: http://www.web2.mnr.gov.on.ca/mnr/forests/public/publications/sil_southern_Ont/toc.pdf

Page 115 – Section 5.2 – Table 5.2.2
Pages 164 to 167 – Section 6.1 – Tables 6.1.4, 6.1.5, 6.1.6, 6.1.7
Pages 178 to 180 – Section 6.1
Page 132-133 - Section 5.3 - Table 5.3.8 Conifer Defects

Details Regarding Changes

1. **Section 5.2 & 6.1 Residual Basal Area Target Tables for Tolerant Hardwoods - Pages 115, 164-167**

An error in transferring numbers to the final document occurred in Tables related to ideal residual basal area targets for managing tolerant hardwoods. The following Tables have been adjusted:
Tables 5.2.2, 6.1.4, 6.1.5, 6.1.6.,**6.1.7**

- The “**Ideal BA**” by diameter class column **did not change**. These are reference points used by prescription writers. Most of the other numbers in the remaining columns have changed, except of course the diameter classes.
- The **Saplings** size class was removed to be consistent with other silvicultural guides and the fact that trees less than 10 cm dbh are rarely marked. Readers should understand that properly managed tolerant hardwood stands under all the scenarios should be growing approximately 1m2/ha of basal area in the sapling size class. The new total residual basal areas could be raised by 1m2/ha for discussions or analysis that involves saplings.

2. **Section 6.1 - Group Selection Harvest Regulation**
   Page 178
   There were a few math errors in the Area Control Example used. The formula boxes remain correct.
   Page 179

The Volume Control formula should have expressed the Volume to be harvested as "m3/ cutting cycle" and not "m3/ha".
Page 180
In the Volume Control example the board foot conversions were slightly off and should be adjusted.

3. **Section 5.3 - Table 5.3.8 Conifer Defects**
   Page 132-133
   The content of a few cells were mixed-up. As well, the recommended action for red ring rot has been modified.

Section 1
Introduction

by Silvia Strobl and David Bland

THE CONTEXT

The information contained in this silvicultural guide applies to the management of forests growing in southern Ontario. This area is represented by Site Regions 6E and 7E (see **Appendix A**). It extends from the Ontario-Quebec border in the east, along the north shores of Lake Ontario and Lake Erie, up the eastern shoreline of Lake Huron to the end of the Bruce Peninsula, around Georgian Bay to Midland, and eastward through Orillia and Marmora to Ottawa.

In several ways, the forests within this region are unlike any others in the province. They have the most diverse tree composition, with more than 60 native hardwood and conifer species growing in a variety of associations (Hosie 1979). There are more different forest types than are found elsewhere. Generally more favorable site and climatic conditions allow the majority of trees here to grow bigger and faster than elsewhere in Ontario. These forests also support a greater diversity of plant and animal species, including far more rare, threatened, and endangered species, than are found in the rest of the province. On average, the forests in this region are much smaller in area and more fragmented than those in other parts of the province and originated after man-made, not natural disturbances. Often they are managed for a multitude of landowner objectives. In addition, a greater proportion of them are severely degraded due to past activities.

The regional context in which these forests are found is also unique. The overall percentage of forest cover within southern Ontario is much lower than in the rest of the province despite the fact that most of this region was once covered by trees. A much larger population density and greater number of roads throughout a region with proportionately less forest cover means that most stands are subjected to greater human impacts on a frequent basis. Increased fire prevention and suppression, forest fragmentation, and the mesic or wetter site conditions in many stands in this region combine to limit fire as a large-scale disturbance factor.

Ownership of forested land is another important difference; in southern Ontario, most of it (i.e., 87 %) is privately owned (OMNR 1993). Furthermore, at least 82 % of the provincially listed vulnerable, threatened, or endangered (VTE) species (excluding fish species) occur on these private lands (D. Sutherland and W. Bakowsky, OMNR, personal comunication 1998). The OMNR Natural Heritage Information Centre tracks rare species in Ontario. To date they have tallied 186 unique species for Site Region 6E and 460 unique species for Site Region 7E (W. Bakowsky and K. Brodribb, OMNR, personal communication 2000).

Forest management in most of southern Ontario that is not on the Canadian Shield occurs in a different context than in the rest of the province. This area is more heavily populated and less forested, and land values are much higher. It has a highly developed economy in which forestry plays a relatively small part. Harvesting, related processing, and forest product manufacturing industries employ a far smaller proportion of the total workforce than the forestry related sector in central and northern Ontario. This contributes to the public position that tends to support the protection of all forest values at least as much as timber extraction.

Regrettably, there is also a lack of information about privately owned forests and landowner objectives for them. Answers to the following questions are still needed. How many landowners are there? How large are the forests they own? Where are they? What is their annual and potential productivity? What is the current volume of merchantable wood? How much is being harvested annually? How are they being managed and used? The most recent survey of landowners was conducted in 1981, and provided information on private lands, landowner characteristics, and descriptions of their forests (Smyth and Nausedas 1981), but it is now out-of-date. Furthermore, the economic importance of the forests of southern Ontario resulting from domestic and industrial wood use is difficult to define due to the movement of wood in and out of the area and the lack of detailed statistics.

The forest industry of southern Ontario is also different. Generally, it is made up of a large number of small operations, both in the logging and primary utilization sectors. Most of the forest industry in southern Ontario is engaged in the secondary manufacture of products from wood harvested in northern Ontario or out of the province. The majority of logging consists of single-skidder operations for veneer, sawlogs, pulpwood, and fuelwood, and most milling is done in small mills with circular saws.

In parts of southern Ontario there is the potential to derive higher valued products from the more productive sites. In these areas the potential economic value added from a cubic meter of wood resulting from careful management can be higher than anywhere else in the province.

These differences have several important implications for forest management in southern Ontario. First and foremost, in most of this region, since so little forest cover remains, silvicultural guidelines should emphasize that the maintenance and protection of this existing cover and all associated forest values take priority over large-scale timber extraction. Second, silvicultural activities must be carefully planned and implemented in ways that not only maintain or improve stand quality, but also protect the site from damage that will affect its important ecological functions such as the provision of wildlife habitat and maintenance of biological diversity. This guide addresses these two management implications and others by providing fairly stringent recommendations and guidelines that were developed to encourage ecological sustainability of forested sites.

Although much has been learned about forests during the last 20 years, these are complex ecosystems that will require further study. Furthermore, most trees are slow growing and site and stand conditions can vary in barely discernible ways that often change over time. Therefore, it may take at least 80 years or more (i.e., one rotation) to better understand just some of the impacts of silvicultural activities on a site or stand. It seems reasonable then, to suggest that landowners and forest managers exercise considerable precaution when managing any forest.

The need for a southern Ontario silvicultural guide

The unique nature of the forests and surrounding landscape of southern Ontario and the lack of an existing silvicultural guide led to the production of this document. Other provincial silvicultural guides exist, including *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario* (OMNR 1998*a*), *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario (*OMNR 1998*b),* and *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario (*OMNR 1997*)*. Also some guides developed in the United States have application to some of the forest stands of this region. However, more specific silvicultural guidelines pertaining to southern Ontario forests are required to help resource managers to determine the most appropriate practices to ensure sustainable forest management in this region. In addition, such guidelines will enable landowners to prepare management plans to qualify for the *Managed Forest Tax Incentive Program* (MFTIP) and provide municipalities with sufficient information to competently regulate the cutting of trees within their jurisdiction.

Excellent opportunities exist in southern Ontario for the prudent application of sustainable forest management. A range of silvicultural prescriptions exist that can not only improve timber production, but also help to protect ecological, recreational, educational, and aesthetic values. Also as more people choose to live outside urban areas, rural perspectives about remaining natural areas including forested lands, are changing. Today more landowners and resource managers not only want to ensure a sustainable flow of forest products from managed forests, but also wish to conserve the non-commodity forest values that can result from sustainable forest management. Landowners deserve credit for their interest in sustainable forest management. Many of them are eager for information that will help them to better manage their land.

Many opportunities for sustainable forest management are found in non-traditional areas. For example, degraded stands provide opportunities for restoration and control of non-native species. Fragmented stands provide opportunties for linkage and subsequent wildlife habitat improvement across a larger scale. In some parts of southern Ontario overall forest area is increasing as abandoned farmland and plantations succeed to immature forests. Many of these younger stands can provide additional opportunities for management. Also some of the older stands could be managed to provide both future old growth forests that are important to many species and high-value veneer logs.

WHAT ARE SILVICULTURAL GUIDES?

Silvicultural guides provide information and recommendations to forest managers, workers, and other interested people on the planning, development, and implementation of ecologically sustainable silvicultural practices. They represent a synthesis of current knowledge, research, and experience.

INTENDED AUDIENCE

This document is intended primarily for use by staff of Conservation Authorities, people who are preparing and/or approving MFTIP plans, forestry consultants, tree-markers, tree bylaw officers, managers of natural areas (e.g., reserves owned by the Nature Conservancy, the Federation of Ontario Naturalists, Land Trusts), stewardship coordinators/councils, woodlot owners, and district foresters in southern Ontario. Some of the information and language are of a technical nature. Readers without a formal background in forestry are encouraged to read selected *Extension Notes,* available from the Land Owner Resource Centre (613/692-2390) and their internet web site: *www.lrc.sympatico.ca*. These clearly written fact sheets cover a variety of resource management topics.

THIS GUIDE

A Silvicultural Guide to Managing Southern Ontario Forests provides numerous guidelines based on research in southern and central Ontario, the Great Lake States, and the northeastern United States, as well as on practical experience with the development and implementation of silvicultural prescriptions in southern Ontario.

The guide describes the important forest types of southern Ontario. Descriptions of the regeneration and growth characteristics of the most important tree species include information about their distribution; preferred site characteristics; associated forest cover; reproduction and growth to maturity; reaction to competition; factors limiting development, growth, and health; and stand structure and dynamics.

This guide provides recommendations for the management of the most important forest types in this part of the province. It explains how to conduct site assessments, and select and implement the most appropriate silvicultural prescriptions designed to promote regeneration, rapid growth, and enable efficient harvest, while minimizing harm to the site, stand, and the greater forest ecosystem. It details regeneration, tending, and thinning procedures for a variety of different forest types, and where applicable, discusses other forest values and their protection.

A Silvicultural Guide to Managing Southern Ontario Forests has relied on two principle sources of information: *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario* (OMNR 1998*a*) and *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993). However the present guide complements these documents through the inclusion of silvicultural practices that better apply to the ecosites and forests types of southern Ontario, especially the hardwood forests. Also this guide addresses regional concerns arising from the high proportion of private land and an often different emphasis on management objectives (e.g., control of invasive non-native species; management of rare forest types or small woodlots; protection of Carolinian, rare, threatened and/or vulnerable species).

LIMITATIONS OF THIS GUIDE

A Silvicultural Guide to Managing Southern Ontario Forests does not address the management of plantations or the *Managed Forest Tax Incentive Program* (MFTIP); this information is available elsewhere.

ORGANIZATION OF THIS GUIDE

Table 1.1 provides a brief summary of the contents provided in each section of *A Silvicultural Guide to Managing Southern Ontario Forests*.

Section 2 provides a summary of good forestry practices and bylaw officers can excerpt it for use. Readers should be especially familiar with **Section 4** as this information provides a critical basis for sustainable forest management.

Table 1.1: Overview of A Silvicultural Guide to Managing Southern Ontario Forests.

Section	Brief description of contents
Section 2	Good Forestry Practices and the Role of Silviculture provides a brief overview of good forestry practices and their relationship to silvicultural activities discussed in this guide.
Section 3	Silvicultural Systems describes the silvicultural practices that are most appropriate for use in the forests of southern Ontario as well as considerations for choosing a silvicultural system.
Section 4	Silviculture and Forest Ecosystem Management discusses important information that influences the selection of the most suitable and effective silvicultural systems including: • the physical setting (e.g., climate, microclimate, physiography, soils, site productivity) • forest ecology (e.g., succession, disturbances, hydrological and nutrient cycling) • regional and historical perspectives (e.g., human impacts on amount of forest cover, stand structure, species composition) • autecology of principle forest tree and exotic invasive species • conservation of wildlife habitat
Section 5	Assessing Stand and Site Conditions • defines forest inventory • explains how ecosites are described by the OMNR Ecological Land Classification (ELC) for southern Ontario • describes 7 general forest cover types and their equivalent ELC ecosites • describes how to analyze stand stocking, structure, and quality in both even-aged and uneven-aged stands • introduces simplified tree classification systems

Table 1.1: *continued*

Section 6	Silvicultural Guidelines describes silvicultural prescriptions applicable to the 7 general forest types in southern Ontario: • Upland Tolerant Hardwood Forests • Upland Oak Forests • Lowland Hardwood Forests and Swamps • Early Successional or Intolerant Hardwoods • Pines (white pine and red pine) • Cedars (white cedar and red cedar) and cedar swamps • Hemlock Each sub-section discusses a forest cover type and gives the equivalent ELC ecosites. A table or key is presented to help to select the most applicable silvicultural systems for the management of the cover type. Then each applicable silvicultural system is detailed. Finally, silvicultural options for unique conditions are discussed.
Section 7	Predicting Effects of Silvicultural Treatments introduces growth and yield research and how information about it can be used to develop silvicultural prescriptions, and presents summary statistics from the first re-samplings of southern Ontario growth and yield plots in 1997, 1998, and 1999.
Section 8	Implementing Silvicultural Prescriptions provides practical considerations for: • vegetation management • tree marking • careful harvesting
Section 9	Literature Cited provides citations for all literature cited in the text.
Latin Name Index	Lists common and Latin names used in text.
Appendix A	Site District Descriptions describes the 2 Site Districts (6E and 7E) that make up southern Ontario.
Appendix B	Autecology of Southern Ontario Tree Species provides summaries on habitat, reproduction, growth, response to silvicultural treatment, and uses by wildlife for most tree species that occur in the forests of southern Ontario.
Appendix C	Performing a Forest Stand Inventory briefly outlines the steps involved in collecting information about tree species composition, density, and structure that are essential to developing a silvicultural prescription.
Appendix D	Guide to Tree Species Suitability for Site Regions 6E and 7E provide an indication of growth productivity for selected tree species growing over a range of field recognizable soil properties.
Appendix E	Stocking Guides for Some Southern Ontario Species presents guidelines on how to use stocking guides and guides for 12 tree species.
Glossary of Terms	Defines technical terms that are used in this guide.

Section 2

Good Forestry Practices and the Role of Silviculture

by Silvia Strobl and David Bland

GOOD FORESTRY PRACTICES

Good forestry practices refers to silvicultural activities conducted in ways that enable the stand to maintain ecological processes and wildlife habitats as well as grow healthy plants. They represent what the forestry profession, forest workers, and society have come to expect from all forest management operations. They have been derived from a recognition that silvicultural activities should lead to ecological sustainability of managed stands by minimizing harm to other forest values and by protecting significant features that help to maintain the integrity and long-term health of the stand.

More specifically they:
- minimize environmental damage to the site (i.e., soil, water, air)
- protect stand components (e.g., trees, associations of trees)
- minimize damage to wildlife habitats
- encourage sustainable forest management
- provide for worker safety
- provide economic benefits to landowners (e.g., growing the right trees for the site, if possible with commercial value, of good quality, in as short a time as possible, with proper and timely stand treatments that combine to maximize landowner return on investment)
- encourage positive public opinion of forestry operations
- reinforce the need for long-term planning.

The importance of planning

Successful implementation of good forestry practices depends on careful planning at all stages of forest management. This planning can help to determine:

- feasible management objectives, based on factors such as site characteristics and land capability, that will not lead to site or stand degradation, or unacceptable loss of critical ecological components
- required information that must be obtained in order to make the best possible management decisions necessary for good forestry practices (e.g., relationship of the site to the surrounding landscape, biophysical characteristics of the site, environmental sensitivity of the site to potential damage, value of site to rare species conservation)
- the full range of possible management strategies that enable selection of the most appropriate option(s)
- management strategies that encourage the best possible growth and survival of desired species
- the schedule of management activities to minimize environmental damage
- how best to protect sensitive features of the site and mitigate damage resulting from forest operations.

Basic rules

Good forestry practice requires adherence to some fundamental rules that are necessary to help meet landowner objectives while minimizing environmental damage, maintaining species diversity, and retaining significant wildlife habitats and other important features. Listed below are some of the more widely accepted rules to encourage good forestry practices.

For a more detailed description of techniques that can be used to minimize the environmental impacts of cutting and timber removal, *A Guide to Logging Aesthetics* by Geoffrey Jones is recommended reading. All modern forest harvesting operations should utilize a careful harvesting approach that is described in detail within **Section 8.3**.

Timing

- To reduce the impact on forest soils and vegetation, try to harvest only during winter months when the ground is still frozen and preferably snow-covered. If this is not possible, harvest in the fall when the ground is dry. Do not harvest in early spring when the ground is thawing or soft and the bark is easily torn from trees. Where possible, avoid harvesting from March 20th to August 31st while sensitive wildlife species are nesting and/or breeding.

Wildlife habitat protection

- Time harvesting to avoid critical nesting and breeding periods.
- Retain recommended levels of canopy closure and buffer protection for pertinent wildlife habitats (e.g., deeryards, raptor nesting areas, riparian habitats).
- Retain nest, cavity, and den trees as well as future snags and mast trees.

Protection of other forest values

- Do not implement silvicultural prescriptions and activities unless they can be conducted without destroying other important forest values such as the provision of significant wildlife habitat or vegetation cover.

Buffers

- Where possible, retain a 30 m buffer of uncut densely growing trees beside open fields or other hard edges to reduce windthrow and other damage to the forest interior and minimize invasion by exotic species.
- Maintain buffers of natural vegetation between cut areas and waterbodies, rare vegetation communities, and significant wildlife habitats.

Tree marking

- Qualified personnel should do all tree marking.

Where to harvest?

- Do not cut in areas with locally or regionally significant habitat features (e.g., fish spawning habitat; seepage areas; clusters of supercanopy trees; abundant downed woody debris; habitats of species of conservation concern such as warblers, raptors, grouse;

areas of dense conifer cover) unless advised to do so or where such cutting is necessary for maintenance of that habitat. These important wildlife habitats are described in detail in **Section 4.4**.
- Avoid cutting along lake and stream shorelines, in wetlands, and around springs and seeps.
- To prevent erosion, cut only on dry slopes less than 35 %.

Roads, skid trails, and landings

- Wherever possible, skid trails and roads should avoid steep slopes (e.g., greater than 12 % for roads; greater than 20 % for skid trails), wet spots, seepage and poorly-drained areas, and intermittent streams.
- Minimize the number and width of skid trails and roads and follow the land contours whenever possible unless seedbed scarification is part of the regeneration prescription.
- Never skid directly up or down a slope.
- Where possible, without lowering product value, skid shorter log lengths.
- Locate landings on well-drained sites away from waterbodies and watercourses.

Crossing streams

- Skid trails and roads should approach and cross streams at right angles to minimize impacts on stream banks and to prevent water from flowing down skid trails.
- Minimize the number of stream crossings, cross at only one location and where the stream is narrow and preferably has a rocky bottom (Archibald *et al.*1997). Remember that it is illegal to destroy any fish habitat.

Cutting and felling

- Use careful directional felling to minimize damage to the residual stand, regeneration, and to the tree that is being felled and to reduce skidding damage (i.e., fell trees so that they can be pulled out of the area as cleanly as possible).

Invasive exotic species

- Hose down forestry equipment between work sites to prevent the introduction of exotic species.
- Remove exotic species to help ensure long-term health of the forest stand.

Promotion of good forestry practices

Under either the *Forestry Act* or the *Municipal Act*, municipal councils can pass tree bylaws to restrict and regulate the removal of trees on private property. These bylaws attempt to conserve woodlots in a manner that protects both individual property rights and the environmental, economic, and social qualities of value to society. They are of concern to both landowners and the logging industry. However the restrictions imposed by these bylaws can vary among different municipalities. Therefore landowners and managers should become familiar with those that could apply to them and then employ good forestry practices to ensure the protection of the site and its associated values, as well as a continual supply of trees for future harvests. For tree bylaws approved under the *Forestry Act*, readers are advised to check with their respective County or Regional municipality. Most municipalities in southwestern Ontario have such a bylaw. Lower tier municipalities (towns or cities) may have a tree preservation bylaw under the *Municipal Act*. Generally, the bylaws apply to trees cut in woodlots of 0.5 ha and larger**.** Some municipalities also regulate cutting on woodlots less than 0.5 ha (i.e., less than 2 acres).

Minimum circumference sizes specified in bylaws have been used and are generally preferred to regulate the removal of trees. This method of regulation is used for its ease of application and enforcement, but is not desirable from a silvicultural perspective. Usually trees with a circumference or diameter of less than the one specified in the bylaws are subject to the regulations and cannot be removed. While this approach concentrates on protecting smaller diameter trees, it frequently has detrimental impacts on the stands under management. For example, in even-aged stands, these smaller trees are often the suppressed trees and mostly represent poor growing genetic stock. Similarly, in uneven-aged tolerant hardwood stands many of the small diameter trees are also suppressed. Without thinning to release those with the most potential (e.g., best form, no sign of disease), it will be much longer than 15 to 20 years before an economic harvest can be obtained again from the stand.

Unfortunately a diameter-limit approach to tree bylaws promotes a diameter-limit approach to forest management, widely considered to be a poor practice. Many landowners and forestry professionals contend that current tree bylaws, even with the addition of several improvements such as the specification of minimum basal areas and leaving some trees over the diameter-limit, still allow or "legalize" exploitive practices such as cutting all and only the large, high-value trees, or cutting only high-value species.

In an attempt to solve the problem of having bylaws lead to unsustainable practices like diameter-limit cutting, a few bylaws include minimum stocking or basal area restrictions (see **Section 5.2** for a discussion of stocking), or require that cutting is done after tree marking by a provincially certified tree-marker (Regional Municipality of Muskoka 1999) to provincial standards (OMNR 2000). All tree bylaws have an exemption for good forestry practice that allows acceptable silviculture.

Bad practices

Most professional foresters and resource managers agree that harmful forestry practices can result in serious environmental damage to the site as well as a decrease in native species diversity, productivity and tree quality with successive cuts, and widespread loss or significant change in the quality of wildlife habitat and rare vegetation communities.

Bad practices usually result from a basic unawareness or deliberate disregard of accepted guidelines for good forestry practices. Some common examples of bad practices include:

- **Harvesting before a thorough pre-harvest site assessment has been conducted.** Minimizing damage to the site and important ecological functions and wildlife habitat requires a good understanding of the most important values of the site and its sensitivity to disturbance, prior to the implementation of forest operations. For example, if workers are unfamiliar with the site, they may improperly locate skid trails, later resulting in soil desiccation, erosion, compaction and/or slumping; or siltation of waterbodies. Or they may not protect significant wildlife habitats or environmentally sensitive areas found in the stand by failing to retain buffers or by poor timing of harvests.

- **Employing methods that simplify the structural diversity of a stand.** By scouring the leaf litter and organic layer, and by removing snags, logs on the ground, and other organic ground debris the nutrient availability for vegetation and available wildlife habitat are both reduced.
- **Allowing livestock to graze in forest stands** (i.e., especially cattle, but also animals such as sheep, goats, fallow deer, elk, and emu). This leads to site degradation, reduction in structural diversity, loss of regeneration of most tree species, and the eventual disappearance of many herbaceous and shrub vegetation species.
- **Indiscriminate felling and skidding due to poor planning, trail layout, or from hurrying operations.** This results in more broken tops and abraded tree trunks, as well as possible site degradation and loss of wildlife habitat.
- **The use of inappropriate equipment.** For example, grapple skidders that must back up to every felled tree, thereby needlessly driving over advanced regeneration and compacting soils.
- **Failure to seek professional advice when owner(s) of the stand and workers are inexperienced and unfamiliar with the principles of forest management.**

Perhaps the most damaging practices in southern Ontario are "high-grade harvesting" and "diameter-limit cuts" because, after repeated use over time, they often result in detrimental changes to the genetic quality of future generations of trees and the loss of sustainable, long-term economic value. Those who employ either or both practices only consider the trees to be removed in terms of their immediate economic value, rather than considering the ecological health of the remaining forest and its ability to produce sustainable future harvests.

High-grade harvesting targets desired species (e.g., all red oaks in a stand) or phenotypes (e.g., all large diameter stems with clear boles); diameter-limit cuts tend to target the fastest growing trees in a stand. Ultimately these methods can result in reduced genetic diversity, stand productivity, and species composition; and lower timber quality because the best growing and best formed individuals are the ones removed in each harvest, leaving successively poorer growing and poorer quality trees as the next crop and as parent trees for any natural regeneration. Also stands with such a history may have an impaired ability to buffer environmental change (e.g., climatic disturbance, insect or disease outbreak) in the future.

Forest certification

Largely due to a growing public awareness of global forest destruction and degradation, increasing numbers of consumers are choosing to buy wood and wood products only from forests that are being sustainably managed to protect the forest ecosystem and to secure forest resources for the long-term. Forest certification programs are one response to this increase in consumer awareness. Briefly, to receive accredited certification, people involved in commercial forestry operations must conduct their forest management activities in strict accordance with established standards that were designed to protect the natural characteristics and ecological processes of relatively undisturbed forests.

One of the guiding principles of forest certification programs is that forests should be sustainably managed. *A Silvicultural Guide to Managing Southern Ontario Forests* can play a role in this process by providing:

- an outline and discussion of the steps that should be followed and the specific information that should be collected prior to the initiation of any silvicultural activities (i.e., the development of a management plan)
- suggestions about how to minimize the environmental impacts of forestry operations
- autecological information about the major tree species in southern Ontario, especially factors that affect their growth, reproduction, and regeneration in this region
- a discussion of silvicultural systems and how to select the most appropriate ones having the greatest potential to enable sustainable forestry to occur on the site
- a discussion of the integration of timber harvesting and non-commercial concerns (e.g., protection of significant wildlife habitat) that can affect how a stand is managed
- some standards for management activities based on experience and research in southern and central Ontario and the northeastern and northcentral United States.

Summary of good forestry practices

Table 2.1 provides an initial checklist and explanation of important components that must be addressed to ensure that forest practices are sustainable. This guide discusses each component listed in this table. Refer to the appropriate section in bold print for more information and where applicable, the quantitative measures that can be used to define good forestry practices.

Table 2.1: Checklist of essential components of good forestry practices.

Component	Description, information required, and function/role
Landowner objectives (Section 2)	• includes revenue from forest products, wildlife habitat improvement, fuelwood for personal use, encouraging old-growth characteristics, recreation, nature appreciation • there are usually several objectives • required to establish management objectives, select priorities, and silvicultural activities designed to achieve landowner and management objectives • objectives should be realistic, and based on an analysis of the subsequent points in this table
Analysis of site suitability/quality (Section 4.1, Section 7, Appendix D)	• information based on soil productivity, suitability of tree species for certain soils and site conditions, history of site/stand, and manager's experience • used to help predict the potential ability of the site to support desired species and suggest possible silvicultural options
History of site (Section 4.2)	• includes natural events such as storms, fire or human land use activities that influenced the development of current site characteristics • may affect management objectives, choice of silvicultural prescription, productivity of site • can require considerable knowledge and experience to interpret the landscape • local landowners may know the history of the site • early surveyor records may provide a snapshot of forest cover at the time of the survey
Wildlife habitat management (Section 4, Tables 4.4.1, 4.4.2 and 4.4.3)	Objectives include: • ensuring that across southern Ontario, applied silvicultural systems maintain the full range of forest types/ecosystems (i.e., by site, age-structure, and vegetation composition), including subtle variations among similar forest types • emphasis on the maintenance of mature forest stands and large forested areas • management for old-growth characteristics on some sites, especially in areas with high potential and/or little or no representation of older woodlands • silvicultural systems that try to emulate natural disturbance patterns and provide diversity of species composition, structure (e.g., conifer cover, mast and cavity trees, supercanopy trees, downed woody debris, variations in canopy closure) of forest stands in southern Ontario

Table 2.1 *continued*

Component	Description, information required, and function/role
	• residual stand diversity and structure of ecologically healthy stands that as closely as possible, reflect pre-harvest stand diversity and structure OR residual stand diversity and structure of degraded stands subject to improvement cutting that eventually improve or are at least maintained • adoption of OMNR wildlife habitat guidelines as minimum standards for selected forest habitats (e.g., for mast, cavity, supercanopy trees; conifer cover; downed woody debris, seeps, riparian areas) and for selected wildlife species (e.g., white-tailed deer, moose, pine marten, raptors, pileated woodpecker) • managing to include or promote mid-tolerant and mast/catkin/fruit bearing species for diversity and habitat/food values
Site and stand inventory (Section 5, Appendix C)	• collects information on land characteristics, trees, and other resource values (e.g., local climate; site conditions; current successional stage of the stand; current tree density; species composition; general health of the stand; presence of other important values such as significant wildlife habitats, waterbodies) • used to set realistic management objectives, develop a forest management plan, schedule forestry operations, provide a foundation for monitoring activities • identifies physically sensitive features (e.g., watercourses, steep slopes) and important heritage, archeological, aesthetic or geological features
Autecology of tree species on the site (Section 6, Appendix B)	• describes the capacity of a species to establish itself and reproduce on different sites as well as its pattern of growth and response to disturbance • helps to determine the suitability of various silvicultural activities • may indicate silvicultural activities that can take advantage of certain traits of a species (e.g., ability to coppice)
Stand management objectives (Section 6)	first: • long-term objectives for the future stand condition should be stated with details on items such as species, sizes, ages, cavity trees, etc. then: • clear short-term or immediate objectives that can be later evaluated through data collection, should be set for each project or operation • common objectives include producing high-value wood products, establishing regeneration, controlling species composition and stand density, reducing losses to insect diseases and fire, enhancing non-timber values such as wildlife habitat and rare species protection • stand management objectives are based on the site inventory and history and consider the autecology of managed species, landowner

Table 2.1 *continued*

Component	Description, information required, and function/role
	objectives, other forest values, and • include recognition of the stand's value(s) to the local landscape in which it is located and how these values might be maintained
Selection of suitable silvicultural system (Section 6)	• selection of the most suitable system is based on all components listed above and is a complete description of the silvicultural activities that will be conducted on the site for the time period specified in the management plan • knowledge of most appropriate tree-marking guidelines; stocking targets; structural, species/age composition objectives; timing and regulation of cutting; location of openings is critical for success • stands with more natural composition and structure can be encouraged by selecting a silvicultural system that most closely mimics natural disturbances
Detailed written silvicultural prescription (Section 6, Appendix E)	• may require professional assistance • should include the transfer of stand inventory summary, stand management objectives (both long- and short-term), and details for exactly how to carryout the project, including targets for tree marking, and habitat protection
Site preparation (Section 8.1)	• use of mechanical means, prescribed burns, chemical treatments to improve the site for crop-trees (e.g., provide suitable seedbed, control severe competition, reduce soil erosion/compaction) • must know where and when to use (e.g., normally not practiced with uneven-aged management of most shade-tolerant species) • specific information required include seedbed requirements of species, effects of each preparation method on site and competing vegetation, timing of site preparation activities • must know the possible ways to minimize environmental damage of silvicultural activities on the site
Tending treatments (Section 8.1)	• designed to control and/or improve trees species composition, growth, and quality • must know when to implement, what trees and other vegetation to remove and retain, and where most appropriately applied • contributes to sustainable forestry by trying to ensure continued forest productivity
Tree marking (Section 8.2)	• for partial cutting operations, tree marking should be done prior to tree removal • requires special skills acquired through training and experience. The province provides certification for tree marking on Crown Land and is developing advanced training for southern Ontario.

Table 2.1 *continued*

Harvesting considerations (Section 8.3; Table 4.4.1)	• minimizing harvest damage to site, regeneration, and residual trees • adhering closely to silvicultural prescriptions • conducting careful harvesting • required information focuses on site topography, especially location of low and steep areas; soil texture, moisture, depth, permeability; drainage patterns on site; seasonal variation of site conditions; location of ecologically significant features (**Table 4.4.1**); best locations for skid trails/log landings; local market demands for wood products; and landowner objectives as described in the management plan • major contribution to sustainable forestry objectives by maintenance of site productivity • prior to harvesting, appropriate operating restrictions should be identified on the ground in Areas of Concern and buffers zones • complete a signed operating contract designed to protect the stand, landowner, and forest operators (see the Extension Note: *Selling Standing Timber* and **Section 8.3**) • methods to measure compliance are recommended. For example, are tree-markers audited for compliance with the silvicultural prescription? Are forest workers audited for compliance with the tree marking? • contact bylaw officer or submit "Notice of Intent" in municipalities with tree bylaws

Section 3
Silvicultural Systems

K. Elliott

E. Boysen

by Ken Elliott, Silvia Strobl and David Bland

INTRODUCTION

Silvicultural systems are a planned series of treatments that are carried out during the entire life of a forest stand with the main objective of controlling the establishment, species composition, and growth of the stand. Successfully implemented treatments also have the potential to produce forest products at present, improve the quality and quantity of forest products in the future, and maintain or enhance a variety of wildlife habitats and recreational opportunities provided by the forest. Numerous factors will determine the nature of treatments and their intensity of application including site quality, quality of the existing forest and its growth potential, markets for forest products, management objectives, and financial constraints.

Silvicultural systems are named for the type of harvesting method used and are divided into two broad categories: uneven-aged systems and even-aged systems.

Uneven-aged forests contain trees of all ages and sizes that are intermixed throughout the site. Usually, there are at least three age classes present. Within managed stands, trees are usually grown continuously without a uniform rotation length until they reach a specified maximum diameter size. An exception occurs in stands being managed for old growth where it is desirable to retain some very large diameter trees. Basal area remains fairly constant except for fluctuations due to mortality or periodic selection harvests followed by ingrowth. The average height of the tallest trees also tends to remain constant over time and the growth protential of individual trees is related to crown vigor and position in the canopy. These stands are managed by maintaining a balance of trees in each of the diameter classes (i.e., basal area) from seedlings through to mature trees (OMNR 1998*a)*.

Even-aged forest stands are comprised of trees that are all within 20 years of the same age. Normally a population of trees of similar age or age class is managed according to the area and volume occupied by the specific age classes (i.e., stands), from their initial establishment to final harvest on a specified rotation cycle that can vary from 50 years to 200 years. A variety of silvicultural techniques is used in even-aged stands to control species composition and quality, and to accelerate the growth of crop-trees (OMNR 1998*a*).

Only shade-tolerant species (e.g., hard maple, beech) can be managed by strict uneven-aged methods (Daniel *et al.* 1979). Species with less shade tolerance (e.g., yellow birch, black cherry, red oak) are better managed and regenerated using even-aged methods, or a modification of the uneven-aged method allowing representation of small, even-aged patches within the uneven-aged stand (OMNR1998*a*).

3.1 DESCRIPTION OF MAJOR SILVICULTURAL SYSTEMS


S. Strobl

There are three major silvicultural systems with each one having some modifications:

1. Selection systems
2. Shelterwood systems
3. Clearcut systems

Selection systems are only applicable in uneven-aged stands while shelterwood and clearcut systems only apply to even-aged stands.

In most of southern Ontario, the selection system or a modification of it is the most commonly used silvicultural system. In some parts of southern Ontario where oak and/or pine forest cover types predominate, the shelterwood system is occasionally used. Use of the clearcut system is rare in this part of the province.

1. Selection systems

Selection systems favor trees that grow well in the shade (e.g., maple, beech, hemlock). While clearcutting and shelterwood systems create even-aged forests, the selection system creates or maintains uneven-aged forests containing trees of different ages and sizes. This system is designed to maintain permanent forest cover despite periodic partial-cuttings. At no time is the complete canopy removed. Instead trees are removed to obtain a target basal area, distributing the trees to be removed across all diameter classes, and never removing more than 1/3 of the pre-harvest basal area. To reach the target basal area and maintain the target basal area distribution over diameter classes, trees of lesser quality are removed first, either individually or in small groups, over the entire stand. Periodic harvests occur on a short cycle (8 to 25 years) and usually establish regeneration following each cut.

The proper selection of trees for harvest is a difficult task and requires considerable training. Forest managers must not only understand how trees grow in order to predict the ones that will do best over the long term, but they should also be able to identify markets for the eventual harvest as well as specific wildlife habitats and other values that should be protected. Usually density levels determine the amount of trees to be cut in each diameter class. Decisions to remove individual trees are based on characteristics reflecting their general health and quality including their vigor and presence of disease and decay; as well as their potential susceptibility to serious risks such as windthrow.

The selection system is best implemented on accessible, highly productive sites consisting mainly of hard maple and other shade-tolerant species.

The relative advantages and disadvantages of the selection systems are compared to those of the shelterwood and clearcutting systems in **Tables 3.1.1** and **3.1.2**.

Modifications to the selection system

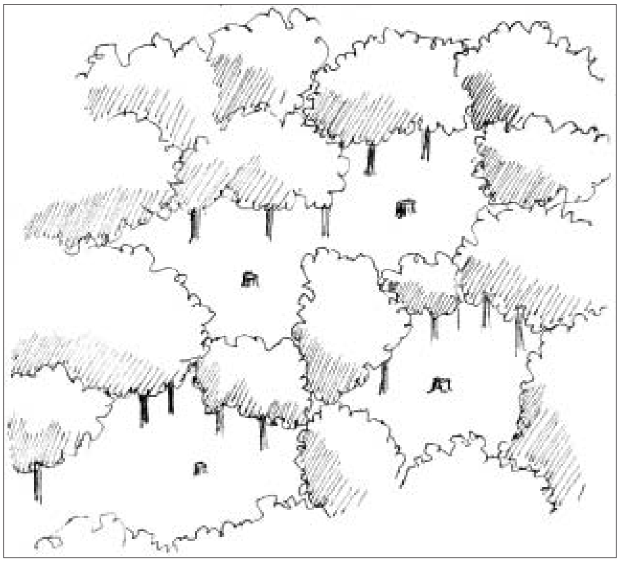


Figure 3.1.1: Aerial view of canopy following single-tree selection harvest showing canopy openings following removal of marked trees.

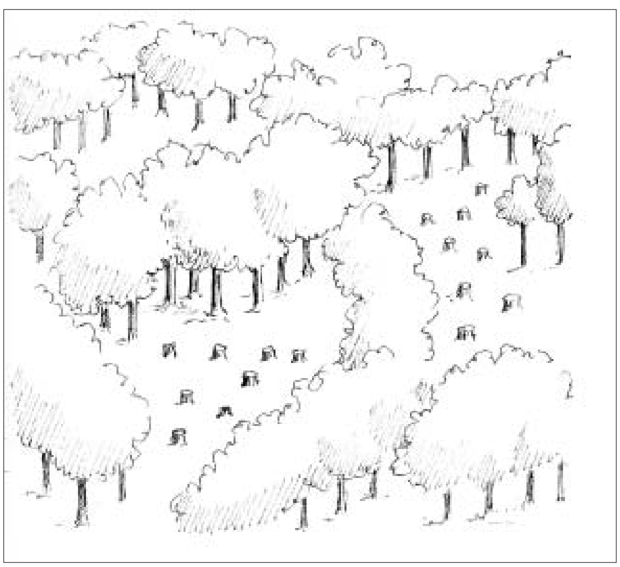


Figure 3.1.2: Aerial view of canopy following group selection harvest showing canopy openings following removal of groups of marked trees.

Single-tree selection

This variation is only used with shade-tolerant species. Single trees are cut and the subsequent regeneration that occupies the remaining growing space is thinned over time to eventually produce another single mature tree. Thinning can occur by deliberate tree removal and/or through natural mortality or self-thinning.

Group selection

This variation removes trees in small groups and thus opens the canopy up more than single-tree selection. It is best used to encourage regeneration of mid-tolerant species such as yellow birch, red oak, white ash, and occasionally the more intolerant black cherry. The goal is to maintain these species within an uneven-aged stand by developing a staged mosaic of even-aged patches that are periodically regenerated in various cutting cycles (OMNR 1998*a*).

This variation could be minor in nature (e.g., by creating an occasional opening to encourage mid-tolerant species), or major, for example, where several group openings are created or when single-tree selection is used in conjunction with it, to remove trees between the group openings. Considerable skill is required to locate the group openings.

2. Shelterwood systems

The shelterwood system involves the gradual removal of the entire stand through a series of partial-cuttings and usually results in an even-aged stand. Normally regeneration is natural but artificial regeneration methods may also be used on some sites to supplement natural regeneration or to shift forest species composition to a more desired condition.

The series of partial-cuttings allows natural regeneration to develop in the stand over time while existing trees are being removed. The new regeneration is protected from excess sun, heat, and moisture until it is well established because the existing trees are removed in stages. The final overstory removal cut is completed when regeneration has met specific targets for size and density. Initial thinning begins with the smaller, shorter trees. The largest and healthiest trees are also usually the best seed trees and are kept in the stand until the final removal.

Under the shelterwood system, the overstory trees are removed in a series of two to four cuts and each cut is done for specific reasons:

- The *preparatory cut* permits the crown expansion of the remaining trees to increase their potential for seed production. Depending on crown size, this cut may not be necessary. This cut also removes undesired species and trees of low quality.
- The *regeneration* or *seeding cut* improves conditions for seedling establishment by spacing the best quality trees with large crowns, increasing seed production from good parent trees, and allowing more sunlight to reach the forest floor. It also permits any necessary site preparation (e.g., soil scarification). This cut is best conducted in or just before a good seed year. Note that it is erroneous to refer to any harvesting with any other system or bad forestry practice as a "regeneration cut"; this term applies specifically to the shelterwood silviculture system.
- The *removal cut(s)* removes the residual stand in one or more operations once the established seedlings, known as advanced regeneration, meet specific size standards.

The relative advantages and disadvantages of the shelterwood systems are compared to those of the selection and clearcutting systems in **Tables 3.1.1** and **3.1.2**.

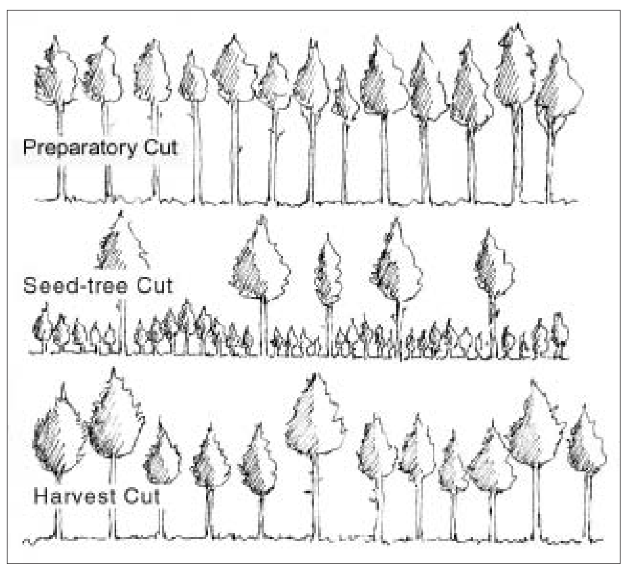


Figure 3.1.3: Diagramatic representation of a typical stand after each cut in a three-cut shelterwood.

Modifications to the shelterwood system

Uniform shelterwood

This modification is used to periodically and uniformly open the canopy throughout the entire stand, and is most applicable where site or seedbed protection is essential and aesthetic appearance is important. Established targets for crown closure are used to control the distribution of residual trees.

Strip shelterwood

Usually, the forest stand is cut in strips, starting on one side with a seeding cut on the first strip. After a few years, a removal cut is made on the first strip and the next strip receives a seeding cut. A few years later, a final cut is done on the first strip, a removal cut on the second strip, and a seeding cut on the third strip. Over time, a series of cuttings progresses strip by strip across the stand (Smith 1986).

Group shelterwood

This modification applies the shelterwood system to areas of up to few hectares in size. Complete canopy removal in the gap does not occur until preparatory and seeding cuts and tending or other cultural treatments have established good advanced regeneration.

3. Clearcut systems

The clearcut system is used to regenerate an even-aged forest stand (i.e., all trees are within approximately 20 years of the same age). All or most of the existing forest is removed from the area in one operation. Clearcutting is usually done in blocks, strips, or patches but can be modified to suit local stand and site conditions.

Regeneration is from one or more of the following sources:

- release of established seedlings
- sprouts from stumps or roots
- seeds existing in the soil seed bank or from mature trees in neighboring stands
- planting of tree seeds or seedlings

This system can result in forest stands with a variety of species; both intolerant and tolerant species may become established in clearcuts. Generally clearcutting is best suited for the management of species that are intolerant of shade (e.g., poplars, white birch, black cherry). These species tend to have the lightest seeds, grow fastest in open conditions, quickly establish themselves and then predominate on the site.

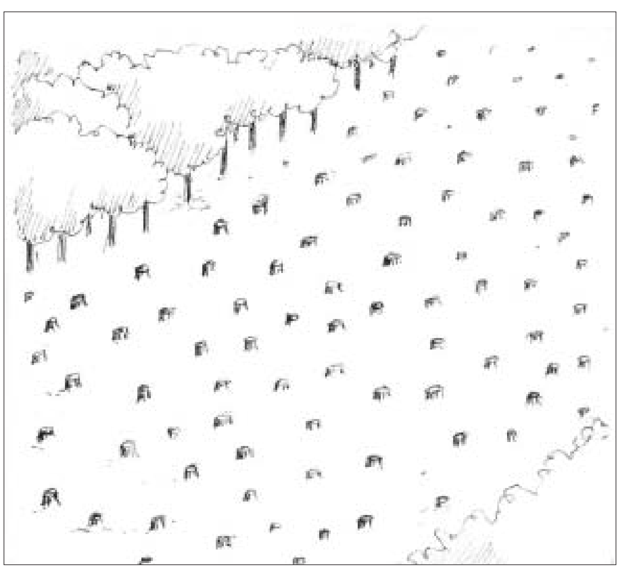


Figure 3.1.4: Aerial view of forest following patch clearcut harvest.

Cutover size is critical if natural regeneration from seeds is anticipated. Forest managers must be aware of average seed dispersal distances of target species and the longevity of seeds in the soil seed bank (**Appendix B**).

Although the clearcut system may be appropriate for regenerating some forest cover types, there are few locations in southern Ontario where the resultant negative aesthetics and potentially detrimental environmental conditions would be acceptable. Therefore extreme caution, careful planning, and consultation with experts should occur before applying the clearcut system or any modification of it. Most forest cover types in southern Ontario should not be managed with the clearcut silvicultural system.

The relative advantages and disadvantages of clearcut systems are compared to those of the selection and shelterwood systems in **Tables 3.1.1** and **3.1.2**.

Modifications to the clearcut system

Seed tree method

Using the seed tree method, all trees are cut, except a small number of isolated or groups of trees that will provide a natural seed source for the site over the regeneration period. This system often requires site preparation and either manual or chemical tending to ensure success.

Selected seed trees must be windfirm and able to survive for several years in the open environment that follows a clearcut. They must also have large crowns capable of abundant seed production. The number of seed trees needed varies according to the target species, the amount of seed produced, average tree and seedling survival rates, and the size and weight of the seed.

The advantages and disadvantages of this method are similar to those of the clearcut system in general. The main advantage is that the seed trees provide a source of seed in the clearcut area for many years after harvesting. Also the remaining trees provide more structural diversity than is found in the unmodified clearcut system. However, the seed tree method of regeneration is essentially inappropriate for maintenance of local gene pools of many forest tree species since there would be insufficient seed trees left to maintain genetic diversity (Gordon 1994). If the stand is isolated (e.g., not within pollination distance from other stands), this method can lead to greatly reduced genetic diversity within the stand (Buchert *et al.* 1997). Also, on many sites, competition from poplar, birch, and raspberries often severely limits regeneration success with this modification.

The success of this method usually depends on the provision of an adequate number of seed trees and their fecundity, as well as proper site preparation following the harvest.

Patch clearcut

This modification is most suitable for use in stands of variable composition, found on broken and irregular terrain. Patch size and shape can be modified to accommodate the site and stand variability and it will often reflect the predominant mosaic in the original forest. Some patch clearcuts create more edge than more regular-shaped clearcuts and therefore may encourage some wildlife species and discourage others.

Progressive strip

The area to be clearcut is first divided into strips and then adjacent strips are cut in sequential order. This method is most applicable for use on relatively flat, uniform terrain, or where forest stand conditions are fairly homogeneous.

Table 3.1.1: Comparison of advantages of the selection, shelterwood and clearcutting systems.

Selection systems	**Shelterwood systems**	**Clearcut systems**
Ecological • emulates small-scale forest disturbances such as windthrow, natural mortality, and isolated insect and disease events that kill single trees or groups of trees • only system that provides or retains habitat for forest interior bird species • maintains forest cover and often creates numerous vegetation layers that are important to many plant and animal species • permanent canopy cover protects the site from wind, desiccation by sunlight thereby reducing risk of fire hazard and erosion by water Forest Management • presence of a permanent source of seed for natural regeneration • well-suited to the management of shade-tolerant species • provides the best way to obtain high-quality sawlogs or veneer logs of some species (e.g., hard maple) Economic • not nearly as expensive as clearcutting and replanting • less expensive than shelterwood systems if site preparation and planting are required due to inadequate natural regeneration • continual availability of high-quality forest products can lead to a steady income Social • maintains good aesthetic quality	Ecological • emulates medium-scale disturbances such as low intensity fires, or small-scale blowdowns (e.g., understory burns that occurred naturally in pine- and oak-dominated forests) Forest Management • natural reproduction is more certain than it is with clearcut systems and likely to be more uniformly established, due to a uniformly distributed seed source, although many white pine stands still require supplemental planting because of difficulties in coordinating regeneration cuts with good seed years • the rotation period is shortened since trees are established and growing before the old stand is completely removed • the partial canopy cover protects the site and new regeneration from weather extremes such as hot, dry conditions, or heavy rain • can encourage moderately shade-tolerant species and somewhat discourage shade-intolerant species by controlling the amount of canopy and therefore sunlight infiltration on the site Social • aesthetic quality of site is better than it is with clearcut systems	Ecological • emulates large-scale disturbances such as widespread fire, insect and disease outbreaks, and blowdowns that create or perpetuate early successional forest stands Forest Management • easiest system to learn and use • harvest operations are all done at once • no residual stand to protect in harvest except where there is advanced regeneration • well-suited to management of shade-intolerant species that require full sunlight

Table 3.1.2: Comparison of disadvantages of the selection, shelterwood and clearcutting systems.

Selection systems	Shelterwood systems	Clearcut systems
Forest Management • requires considerable training and supervision to properly implement • requires a larger area to meet volume needs • high risk of damage after cutting to both site (e.g., rutting) and residual stand if harvesting operations are not done properly and/or at the right time of year • will not regenerate intolerant species • high level of crown closure will discourage regeneration of mid-tolerant species Economic • requires a good market to accept hardwood pulpwood and fuelwood since a disproportionate amount of low-quality products usually need to be removed during the early cuts	Ecological • dramatically alters much wildlife habitat, especially for species requiring high canopy conditions Forest Management • greater technical skill is required to design the overall system for site preparation and harvest operations to accommodate residual trees, and to mark trees for removal and seed production • need to protect residual trees and minimize logging damage to regeneration during preliminary cuts • slash provides a source of fuel for fire that could potentially damage new regeneration Economic • need a market for the low-quality material that is usually cut first • multiple harvests can be expensive and immediate logging costs are higher than for clearcut systems	Ecological • possible reduction of genetic and species diversity of site • wildlife habitat is drastically altered and most species that were highly dependent on the stand before harvest will be replaced by other species asssociated with early successional habitats • site preparation for artificial or natural regeneration can damage soil structure • openings make the site more vulnerable to soil erosion and desiccation • on some sites, may result in changes to the water table (e.g., usually causing a rise in its level) Forest Management • hot, dry conditions in large openings can hinder establishment of regeneration • large amount of slash on ground after harvest can be a potential fire hazard • relying on natural regeneration is rarely successful unless intolerant hardwoods such as white birch and poplar are the desired species • stands will not produce marketable wood products for a long time • competition from non-crop competing vegetation may be intense Economic • may require high investment in site preparation, artificial regeneration, and tending Social • often unpopular with the public because of poor aesthetic appearance of site after clearcut

3.2 CHOOSING A SILVICULTURAL SYSTEM

The choice of a specific even- or uneven-aged silvicultural system is based primarily on the growth and regeneration characteristics of the target species, the current condition of the stand, the potential of the stand based on its ecosite, and the management and landowner objectives for the site. Selection of a system should also consider: the proximity of the stand to other stands in the landscape (i.e., seed and pollen sources); the size and shape of the stand; the management implications for wildlife habitat (e.g., interior forest songbird habitat); the risk of windthrow and invasion of exotic or undesirable species; and the risk of disrupting or fragmenting any remaining continuous forest cover in the region. Planning and careful consideration of all options are important.

As a general rule, forest managers should select the silvicultural system that most closely emulates the natural ecological processes and succession that would most likely occur in the stand to be managed, and that produces a forest with more natural composition and structure. Refer to **Appendix B** for a summary of the autecological characteristics of tree species of southern Ontario.

Forests managers and landowners are advised to consider the following factors when choosing a silvicultural system:

- contribution of the stand to forest landscape (i.e., is it a core, interlinked, or island of forest cover?)
- goals for the forest stand
- current stand and species characteristics
- species desired for regeneration and their autecology
- local climate and site potential
- fish and wildlife concerns
- environmental concerns and limitations
- natural heritage concerns
- nature of current and future markets

Contribution of stand to forest landscape

Managers must consider each stand in relation to the overall amount and types of forest cover within the larger region. In areas with little remaining forest, almost any stand is likely important to wildlife species that are dependent on forest habitat. Therefore silvicultural intervention should not drastically alter such stands. Often, individual stands provide important regional representation of unique or rare characteristics such as structure (e.g., large downed woody debris), age (e.g., early successional, potential old growth), and species composition (e.g., rare or uncommon species). Sometimes, the size and location of a stand can help managers determine its contribution to the conservation of ecological values. For example, small, isolated stands surrounded by anthropogenic land uses frequently have lower natural heritage (i.e., conservation value) than larger stands located amid more natural surroundings.

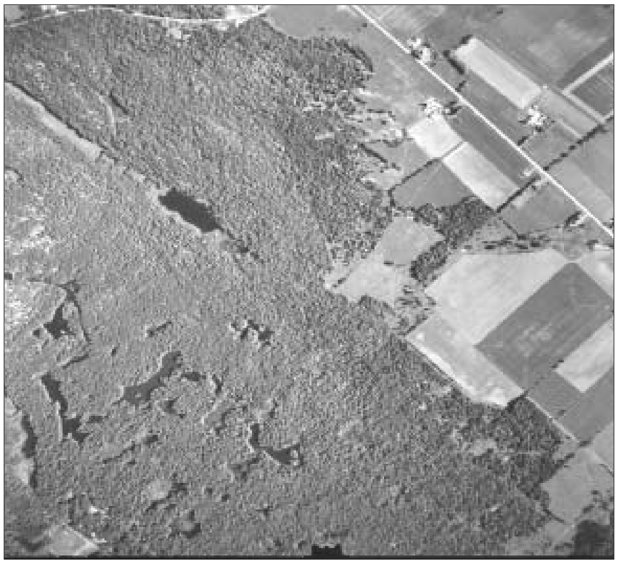


Figure 3.2.1: Typical example of a core forest in southern Ontario (aerial view).

Core forest refers to unbroken blocks of forested land of more than 100 hectares in size that contain large areas of interior forest. These areas support species and genetic diversity that are important on a regional scale. They also provide critical habitat for many plants and animals, including some species that are becoming increasingly rare in southern Ontario because these larger tracts on which they depend are disappearing. In parts of southern Ontario where such stands are rare, the use of more intensive silvicultural systems such as group selection and shelterwood is probably inappropriate if protection of a suite of forest values is valued. Also all silvicultural or harvest operations within these core forest areas must be planned to provide a shifting mosaic of forest cover types over time; single, large operations should be discouraged.

Figure 3.2.2: Typical example of an interlinked forest in southern Ontario (aerial view).

Interlinked forest refers to broken blocks of forest (< 100 ha) interconnected by corridors of treed fencerows, riparian areas, or other natural areas. They permit better movement by wildlife and exchange of genetic material than do isolated forest islands. However they have more forest edge per hectare than core forest and are more susceptible to invasive species than core forests. Interlinked forests are excellent candidates for forest restoration. Gaps between interlinked forests can be reforested to create larger core forests. Managers should consider retaining or planting buffers of native vegetation along forest edges and removing invasive exotic species.

Forest islands are small, isolated stands with an abundance of forest edge. Invasive species are more common. They are usually too small to support larger animals and species dependent on interior forest habitat. Unfortunately these areas can function as population sinks by attracting numerous species to an environment in which they will succumb to predators or fail to successfully raise their young. Over time, local populations of these species decline and may disappear altogether.

Extensive effort is required to restore core forest by enlarging existing forest areas, improving forested corridors linking forest islands, and reforesting selected open areas between islands. In many forest islands, there is less concern about the negative impacts on wildlife habitat resulting from intensive silvicultural treatments such as group selection or shelterwood because these areas usually support far fewer plants, animals and species of conservation concern than larger core forests. Managers might consider regenerating isolated forest stands to mid-tolerant and intolerant species, but such silvicultural treatments will often require follow-up tending and/or planting, especially if seed sources for natural regeneration are distant.

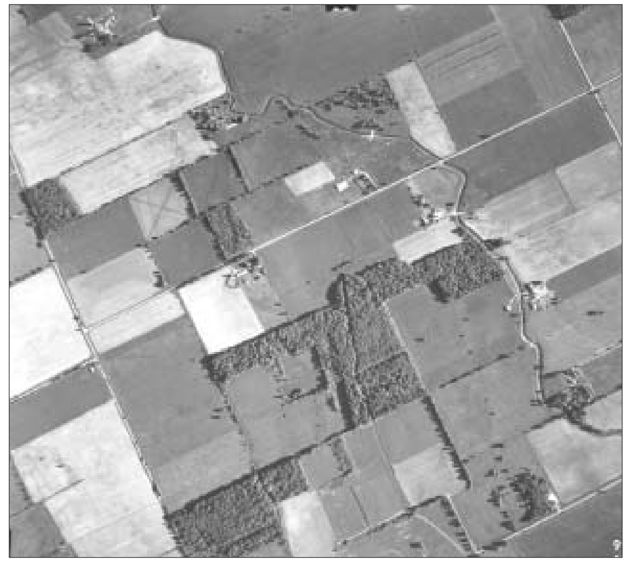


Figure 3.2.3: Typical example of a forest island in southern Ontario (aerial view).

Goals for the forest stand

The choice of a particular silvicultural system depends largely on the long- and short-term goals for the forest stand. Common goals might include obtaining long-term economic return from sustainably harvested timber or maple syrup production, removal of selected trees over time while protecting the aesthetic appearance and ecological integrity of the stand, or encouraging the growth of certain tree species while also providing habitat for a diversity of wildlife.

Each silvicultural system has advantages and disadvantages that landowners and managers should clearly understand. The selection system is most appropriate if maintenance of forest cover for wildlife habitat and a continuous supply of timber, fuelwood, or maple syrup, are important. However intolerant species may not do well if the openings are not large enough. Group selection or shelterwood are the the best choices if the goal is to regenerate mid-tolerant species like oaks. Although costs can be somewhat higher, these are usually offset by the higher value of harvested trees in southern Ontario. Due to ecological and aesthetic concerns, and the shade tolerance of some of the species of tolerant hardwood forests, the use of the clearcut system in southern Ontario is usually discouraged by most forest managers and therefore is not generally recommended.

Current stand and species characteristics

An assessment of the tree density, health, age, size, and species composition of the forest stand helps to determine the volume and value of the trees in the stand and the amount of work required to realize specific objectives. Other characteristics such as the presence of cavity trees, snags, and mast species that produce fruit and nuts are important to note because of their value to numerous wildlife species.

The size of the forest stand is important. Large stands permit the incorporation of more variation in management plans; some areas of the stand may be cut while maintaining some uncut areas. Small stands may preclude the use of some silvicultural systems.

If the current stand resembles the desired stand, management prescriptions can concentrate largely on characteristics that will maintain the current stand. Usually more intensive management is required for stands that do not currently exhibit the desired characteristics.

Species desired for regeneration

Different silvicultural systems favor the regeneration of different tree species. Therefore the identification of species to be regenerated helps to determine the most appropriate silvicultural system for the stand.

The selection system is preferable when regenerating tolerant species, such as maples, beech, and hemlock, that are currently in the stand. This system can also be used to maintain a forest with more mid-tolerant species, such as red oak and white ash, if group selection is applied as well. In both cases, seed sources come from trees in the stand and regeneration is natural. Natural regeneration methods can also be used to establish tree species that grow in adjacent forests, provided they have light-weight seeds that can travel to the site.

If regeneration of mid-tolerant species such as red oak or white pine is desired, the shelterwood (and occasionally the group selection system) is most appropriate. On some sites, natural regeneration may be supplemented by artificial regeneration, including seeding, planting, and the stimulation of coppice growth.

Artificial regeneration methods are often used when the desired species do not grow in the vicinity of the stand. Then the desired species are obtained from nurseries and either planted or directly seeded on the site. However artificial regeneration will increase the cost and time associated with management of the site. Direct sowing of seeds collected from nearby sites may work for species like oaks and hickories with large seeds, provided that predation by squirrels is not a problem.

Planting may also be used to supplement natural regeneration when too few seedlings have become successfully established through natural regeneration. If planting is anticipated, managers will need to ensure that seedlings are obtained from appropriate seed zones (see **Figure 4.1.4**).

Frequently some control of competing vegetation may be required to allow slower growing tree species to become established. Options for control include manual weeding and the use of mulches, prescribed fire, and herbicides. Whenever applicable, these options should be examined, concerns identified, and alternatives explored. Since prescribed burns and herbicides can have potentially detrimental effects on the forest environment and surrounding region, their application should only be conducted by experienced professionals.

Local climate and site potential

Although many tree species can grow over a range of sites and conditions, their survival and growth vary considerably with local climate, soils, and bedrock type. Knowing the site conditions of a stand can help to identify those species best suited to the site. Such knowledge can also provide an indication of expected growth rates. In general, if the tree species in the stand are healthy and growing well, they are probably appropriate to the site. On the other hand if the trees are growing slowly and/or show higher than normal levels of disease, they may not be the best species for the particular site conditions. Refer to **Appendix B** for a summary of the autecological characteristics of important tree species.

Basic information includes some knowledge about the forest region in which the stand is found (e.g., Great Lakes-St. Lawrence or deciduous forest zone); the type of bedrock that underlies the stand (e.g., granite, limestone); the landform (e.g., kame moraine, lacustrine plain); the depth and texture of soil (e.g., sand, silt, clay); the drainage of the site; the amount and seasonal distribution of precipitation on the site; how hot the site gets in summer; and the length of the growing season.

From the start of forest management planning, the potential and physical characteristics of the site should influence landowner objectives for the stand. For example, an infertile site should discourage the development of a sugar bush operation; a hilly site should confine timber harvesting to flatter areas.

Fish and wildlife habitat concerns

It is important to protect and maintain wildlife habitat on the site. For example, some mast producing trees and shrubs such as cherries and oaks should be retained, as well as cavity trees that are important to nesting birds and denning mammals. Some large trees of current or potential use to nesting raptors (i.e., hawks and owls) should also be retained. Fallen logs and large limbs, and standing snags also provide additional habitat for birds, mammals, reptiles, amphibians, and many invertebrates (see **Section 4.4** and refer to the Extension Notes *Cavity Trees are Refuges for Wildlife* and *Restoring Old-Growth Features to Managed Forests in Southern Ontario*).

In addition to the provision of wildlife habitat, down and dead woody debris is desirable to have on a site for several other reasons: to provide nutrients, moisture-holding capacity, thermal moderation, and seedling sites; and to mitigate pollutants such as nitrogen.

Timing of foresty operations and location of roads, skid trails, and stream crossings should be designed to protect significant wildlife habitats such as nests, seeps, and creeks and to avoid disturbing wildlife during the breeding and nesting seasons.

Generally, single-tree selection will affect mature interior forest wildlife habitats less than the other silvicultural systems. However, over the short-term, modifications of the shelterwood and clearcut systems (e.g., patch cuts) can be used to improve food supplies for some wildlife.

The openings that are created often attract small rodents and other prey species for larger carnivores and encourage the regeneration of poplars and shrubs that provide forage for browsers, ruffed grouse, and other wildlife.

Since it is illegal to destroy fish habitat, the protection of riparian areas along water bodies and watercourses is critical. Buffers of natural vegetation in these areas are essential because of their ability to moderate the aquatic environment (e.g., provision of shade to maintain cooler water temperatures), protect it (e.g. from erosion), and to provide food (e.g., insects). However buffers have other important functions as well. They often add to the diversity of a forest stand, sometimes at a regional level of importance. In many stands in southern Ontario, floral diversity is higher in riparian areas than in the adjacent forest. In addition, many animals use these areas as corridors for traveling across the landscape.

Environmental concerns and limitations

Forest stands located on slopes or hills are more susceptible to erosion and general soil loss than stands growing on more level terrain. Therefore when harvesting trees from any slopes, a partial-cutting silvicultural system is preferable. Also, harvesting in low-lying depressions and other areas where the water table is close to the surface should be confined to the winter months.

Natural heritage concerns

Where all or part of a stand has been identified as having significant natural heritage value on a regional scale (e.g., ANSI, ESA, habitat of a rare or endangered species), landowners should be strongly encouraged to leave at least a portion of it uncut, even though it may be commercially valuable.

For example, many songbird populations are declining, often because their habitat is disappearing. The Recovery Plan for the Acadian flycatcher and hooded warbler recommends keeping a permanent, undisturbed, core area to provide the closed canopy habitat required by the Acadian flycatcher, as well as many other forest birds. Therefore supportive landowners might consider leaving perhaps 10 ha (22 acre) in the center of the forest as an ‘old-growth’ reserve. Or landowners with woodlots used by hooded warblers might be encouraged to maintain some habitat for this threatened species. The small natural canopy gaps that make up about 10 % of the area of mature growth forests create excellent nesting sites for this species.

The Acadian flycatcher and hooded warbler Recovery Team is encouraging public agencies that own or manage Carolinian woodlands to maintain about 30 % of them as mature growth forest (M. Cadman, Canadian Wildlife Service, personal communication, 2000). This commitment would greatly enhance the future survival of local populations of Acadian flycatchers, hooded warblers, and numerous other Carolinian species. This guideline could also be considered in other areas, for example, forests with known nesting records of the vulnerable cerulean warbler.

Nature of current and future markets

Forest management often involves sizeable investments of time and money, as well as the prediction of when optimal financial return can be obtained. The immediate removal of some trees from the stand is an option within all silvicultural systems. However, the number of trees removed, and the time period between harvests should be determined and clearly explained within a management plan to ensure long-term regeneration, growth, and maintenance of the stand. The actual harvest prescription (e.g. improvement cut, veneer/sawlog cut) would depend on the existing stand structure.

Landowners should be aware that delaying a harvest of small-diameter sawlog trees will substantially increase their economic return. This must be kept in mind whether planning for selective thinning of immature hardwood stands or for harvest of mature stands. For example, a logger in the year 2000 may offer a landowner $400 to $500 per 1000 bd. ft. for superior quality 2.6-m (8.5-ft.) butt logs from standing sugar maple trees that average about 30 cm (12 in.) DBH. These trees are the future of the stand. The average return from each of these trees would be 36 bd. ft., based on an average of one 2.6-m (8.5-ft.) butt log, with an inside the bark measurement of 11 in. at the top (scaled) end of the log. It would take 28 trees of this size to make up 1000 bd. ft. of sawlog material within the butt logs, for the return of $400 to $500, assuming a height of 11.6 m (38 ft.) to the point of heavy branching. The stem above the butt log will provide, at the most, one additional small sawlog of lower value, and pulp or firewood. Assuming another log could be taken above the butt log, the net volume from each individual tree would still be less than 75 bd. ft., according to the Ontario Log Rule, Form Class #79 method of estimating the approximate volume of standing timber (OMNR 1995).

However, if the landowner were to selectively harvest only the mature and defective trees now, in 12 to 15 years these small sawlog trees will continue to accrue volume and grow into a diameter size with considerably higher value. On average, with selective thinning, these superior quality 30 cm (12 in.) DBH stems will grow to 38 – 40 cm (15-16 in.) DBH. The diameter at the top end, inside the bark, of a 2.6-m (8.5 ft.) butt log will be 33 – 36 cm (14-15 in.), and is eligible to meet the criteria for high-grade veneer. Assuming the trees have no defects, these standing trees will then fetch grade one or grade two veneer prices. In early 2000, these prices could be as high as $3500 for 1000 bd. ft. By waiting, the total volume of the butt log could almost double to 61 bd. ft., with an increased value of 200 to 800 % per bd. ft., according to present-day values. Moreover, it would require the harvest of 17 trees or less to make up 1000 bd. ft. from the butt logs. In addition, there may be another grade one or grade two veneer log above the first 2.6-m (8.5-ft.) butt log in each tree, plus additional sawlog material to the heavy branching at 11.6 m (38 ft.). The net volume for each individual tree, assuming no defects, would be approximately 200 bd. ft. with veener and sawlog volume combined, according to the Ontario Log Rule, Form Class #79 method of estimating the approximate volume of standing timber (OMNR 1995). Depending on previous management and site productivity, it has taken 50-80 years for the tree to attain 30 cm (12 in.) DBH. Giving it another 12-15 years will more than double the volume and multiply the value by 400 %. Few other investments can do that.

The above example assumes no increases in veneer prices over the next 10- to 15-year period. Historically, it has been difficult to predict market trends and the magnitude of future increases in wood prices, but generally high-grade material prices have increased over time. For example, 10 years ago when OMNR staff offered tree marking services to private landowners in southern Ontario, the best price for sugar maple veneer was $200 per 1000 bd. ft. because there was a very weak or non-existent veneer market for hard maple. Now, the top grade of hard maple veneer is in high demand in the United States and this market demand has driven prices up to $3500 for the best quality, but an approximate average of $1000 for 1000 bd. ft. (D. Pridham, OMNR, personal communication, 2000). One can only speculate what the price of hard maple veneer will be in another 10 years, but prudent landowners will anticipate such future increase in wood value and orient their management objectives towards producing smaller volumes of higher quality and value, veneer and sawlogs.

Summary of some basic guidelines

- Since most forest trees grow slowly, set realistic expectations and provide the best conditions for rapid tree growth when these do not seriously threaten other important forest values.
- If permanent forest cover is important for aesthetic, ecological, and/or environmental reasons, a partial-cutting system is recommended.
- Plan how and when regeneration is going to be introduced into the stand.
- The less shade-tolerant the tree species desired, the larger any canopy opening should be to encourage regeneration, establishment, and growth of these species. For example:
    - If sugar maple (a species that can live and grow in shade) is desired, single-tree selection is the best option.
    - If red oak (a species that needs some light to become established and grow well) is desired, group selection or the shelterwood system is the best option.
    - If aspen (a light-demanding species) is desired, clearcutting is the best option.
- In general, a more diverse forest, containing a greater number of species and range of tree sizes and ages, will provide a wider range of habitat options for a larger variety of animals.

Section 4

Silviculture and Forest Ecosystem Management

by David Bland and Silvia Strobl

INTRODUCTION

Today, managers integrate research findings from forest ecology and their knowledge of site conditions and the requirements of tree species, to help them manage forests for the sustainable and long-term provision of forest products and other values. They no longer manage stands in isolation from each other, but in relation to other stands in the region and the surrounding landscape. Site activities try to avoid increasing the overall amount of detrimental forest edge and stand fragmentation because of their negative impacts on the ecology and biodiversity of the stand and surrounding areas.

Increasingly, managers employ silvicultural treatments designed to mimic natural disturbances to provide a range of forest types, at different stages of succession, of value to wildlife as well as humans. For example, the removal of several trees using group selection emulates the canopy gap that might be created by windthrow of several trees, creating an opening of sufficient size, to permit light conditions within the stand that favor the growth of mid-tolerant species.

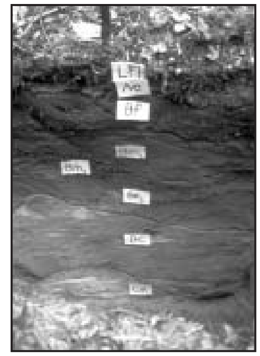
At the stand level, they use their knowledge of site conditions and biology of tree species, to manage specific stands through silvicultural activities designed to work within the natural limitations of the site and tree species biology. For example, using a shelterwood system, large, high-crowned trees with thick bark are retained for seed production because they most resemble those trees that would survive a fairly intense, natural fire, and are likely to be the best seed producers. Managers conduct prescribed burns to improve site conditions for the establishment and growth of species such as red oak, that are adapted to wildfires. They improve the regeneration of red oak by taking advantage of its natural ability to coppice. They retain cavity trees to not only accommodate the needs of numerous wildlife species, but also to provide additional forest structure and recycle essential nutrients, after these trees fall and later rot on the forest floor.

Today, managers use the most appropriate and sustainable forestry practices to:

- minimize the loss of significant wildlife habitat and native biodiversity
- minimize damage to the site and stand, forest fragmentation, and creation of forest edge
- retain or improve forest structure
- avoid the introduction of exotic species

This section describes the important abiotic factors, and some of the aspects of forest and species ecology that managers and landowners should understand in order to develop suitable silvicultural prescriptions. It concludes with a summary of significant wildlife habitats and suggested silvicultural treatments and guidelines to encourage their long-term existence.

4.1 KNOWLEDGE OF THE PHYSICAL SETTING


E. Boysen

The development and implementation of appropriate silvicultural prescriptions require an understanding of the physical setting. Site conditions such as micro-climate, soil characteristics, and aspect influence the potential for growth, regeneration, and future quality of selected tree species. They also suggest the most suitable methods of harvest; silvicultural impacts on aesthetic values, wildlife habitat, and soils; potential risks from weather, windthrow, insects, and disease; and appropriate rotation length.

Managers should be aware of the following abiotic factors.

Climate

Climate influences species range and individual tree growth rates. **Figures 4.1.1, 4.1.2 and 4.1.3** show the range in variability in extreme temperature, precipitation, and growing degree days respectively, that affect tree growth in southern Ontario. Study of this variability has led to the delineation of tree seed zones (**Figure 4.1.4**) that represent fairly uniform growing conditions within southern Ontario (OMNR 1998*c*). These zones are based on detailed climatic information, derived from the Ontario Climate Model, and results of tree seed source studies.

Knowledge about climate and species can be used to:

- identify species growing at the northern or southern edge of their range that need protection from harvest or alterations to silvicultural prescriptions to both preserve the parent seed trees and promote regeneration. **Appendix B** notes those tree species growing at either the northern or southern edge of their range. Some forests, comprised largely of tree species growing at the edges of their natural geographic ranges, are probably quite vulnerable to the extreme climate changes envisioned for the future (Cherry 1998).
- identify species that could be introduced into degraded woodlots by supplemental planting, based on their native range
- identify biologically appropriate seed zones from which supplemental planting material should originate, to ensure it will be adapted to the climatic conditions of the forest stand
- determine the interval between partial harvests in the same forest stand. This interval will be shorter in areas with better growing conditions (i.e., greater number of growing degree days per year, more fertile soils) and/or with less shade-tolerant, faster growing species.

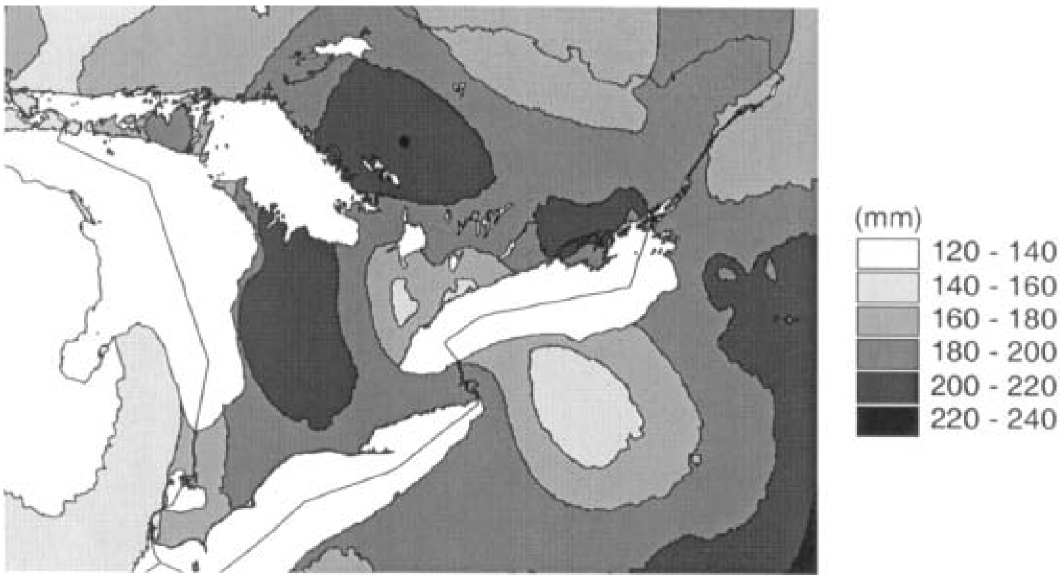


Figure 4.1.1: Precipitation for the three-month period prior to the start of the growing season (from: MacKey *et al.* 1996).

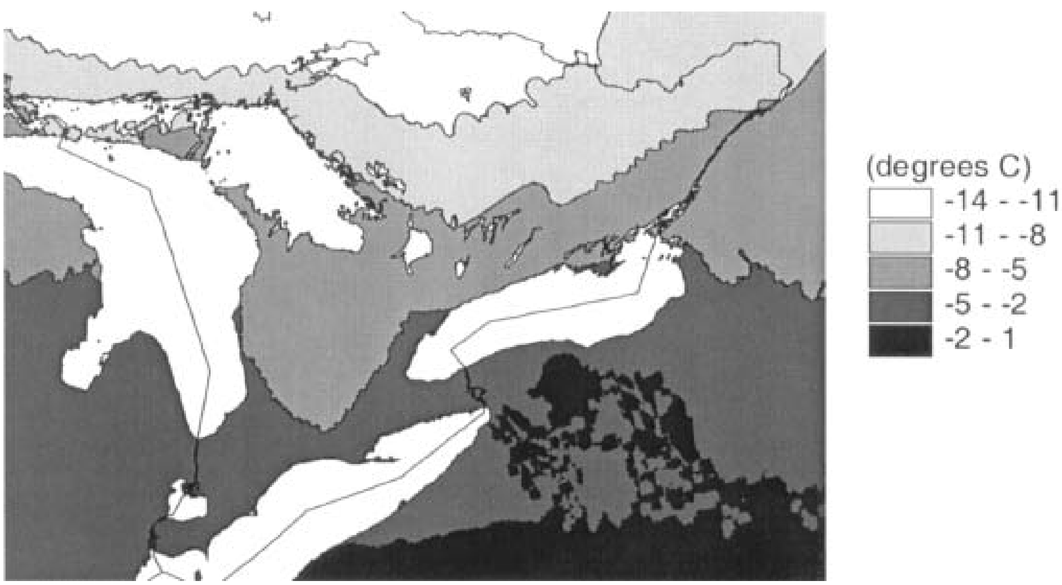


Figure 4.1.2: Range of mean temperature of the coldest month of the year (from: MacKey *et al.* 1996).

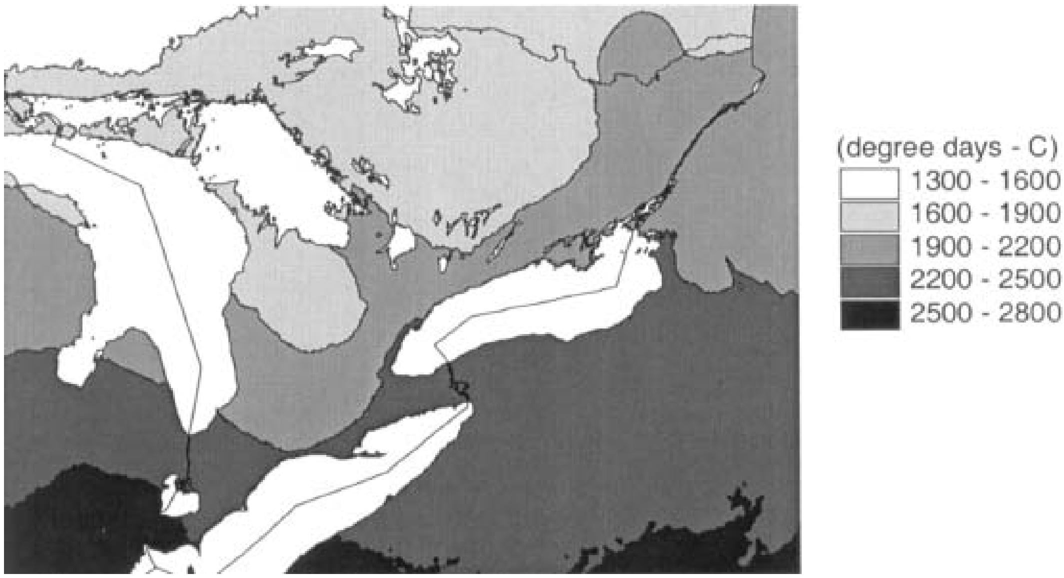


Figure 4.1.3: Growing degree days (from: MacKey *et al.* 1996).

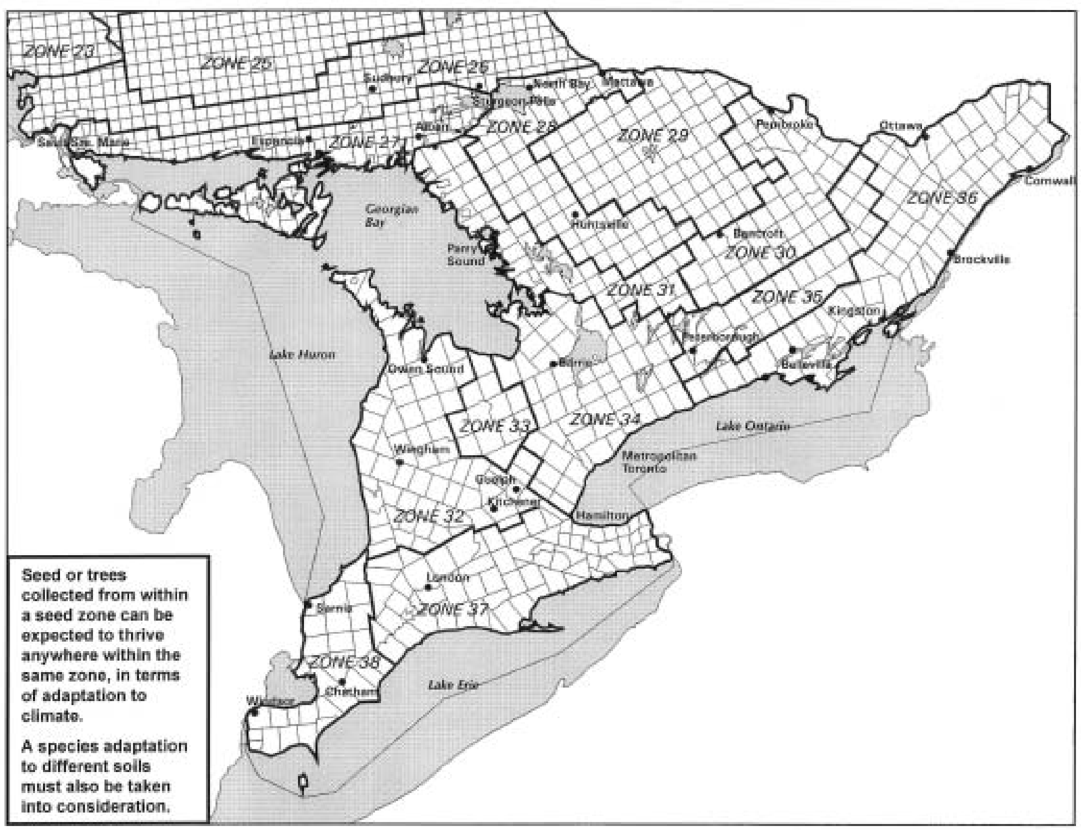


Figure 4.1.4: Tree seed zones and township boundaries of Ontario (from OMNR 1998*c*).

Microclimate

Microclimatic conditions can influence species composition and distribution on a site. For example, cooler, moister air conditions on north-facing slopes and in valleys favor conifers such as eastern hemlock; warmer, drier air conditions favor oaks and hickories. Microclimatic conditions may also improve growth rates, tree form, and vigor. For example, trees growing at the edge of a stand or gap may grow faster due to the greater availability of sunlight. Trees growing on ridges, bluffs, or hilltops may be more susceptible to sunscald and windthrow. Frost damage can occur in low-lying areas (frost pockets) where cold air drains.

Knowledge of microclimatic conditions helps to determine the most appropriate management activities for the stand. To encourage the development of regeneration, managers might create openings on south-facing slopes of hillsides to provide more direct sunlight for the regeneration. On some sites, local microclimatic conditions will restrict access to the stand (e.g., wet soils, unfrozen ground), thereby influencing the timing of silvicultural activities.

Physiography

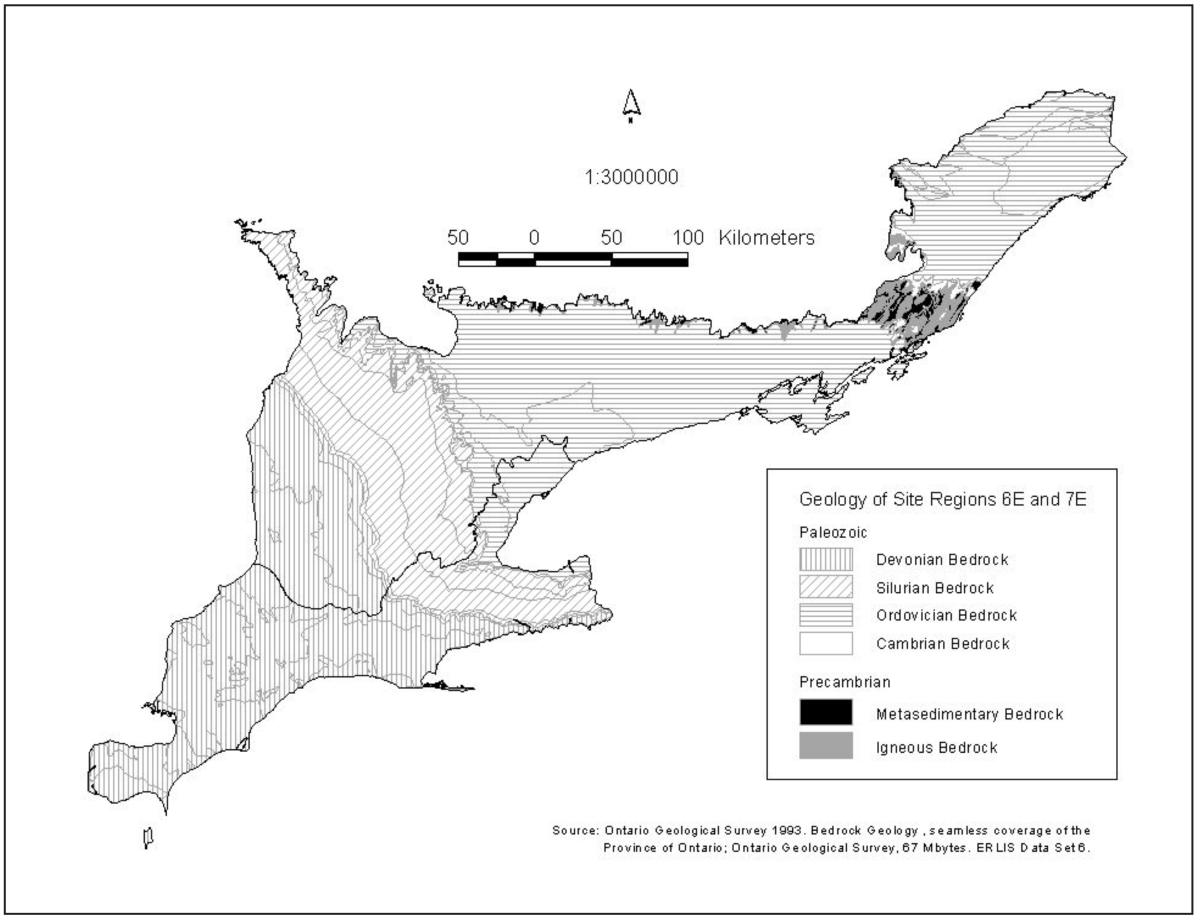
In southern Ontario, past glaciation, lacustrine and marine deposition, and water-level fluctuations have left a variety of distinctive deposits (e.g., lacustrine clay and sand plains, drumlinized till plains, granitic rock outcrops). An awareness of this regional physiography can help to explain the composition, distribution, and potential productivity of forest stands because of the effects of physiography on local topography, and soil and drainage conditions. For example, in some areas, bedrock overlain by shallow sand may indicate a locally rare forest stand type.

In parts of southeastern Ontario (e.g., Prince Edward County) extensive limestone plains are common. These are generally flat to gently sloping, with very shallow or only scattered surficial deposits of poorly developed soils, with poor drainage conditions that limit stand productivity. In other areas (e.g., the Frontenac Axis), erosion resistant Precambrian granitic and gneissic bedrock strongly influence the forest cover of the region. Once scoured by glaciers, many rock ridges are bare or covered with thin, somewhat acidic and infertile, sandy soils. In this region, forest productivity is usually higher on deeper, well-drained, more fertile and basic soils derived from marble bedrock.

Throughout much of southwestern Ontario, lacustrine clay, sand, and till plains dominate the landscape. Here, forest composition often depends largely on soil moisture conditions due largely to small changes in local relief and the presence of seepage areas. Soil texture also affects the distribution of several species in this region. For example, American chestnut, black oak, cucumber magnolia, tulip tree, and eastern flowering dogwood are rarely found on clay soils but prefer coarser soils (e.g., sands).

Generally, in southern Ontario, sites underlain by Paleozoic limestone bedrock tend to support higher productivity and species diversity of hardwood species, than sites underlain by the Precambrian granites and gneisses (e.g., the Canadian Shield), where other factors such as local climate, soil depth, and drainage are similar.

Figure 4.1.5: Bedrock geology of southern Ontario.



Soil characteristics

A basic knowledge of soil conditions helps managers and landowners to provide an initial assessment of potential site productivity. It can also help to guide silvicultural activities, especially those that are dependent on drier soil conditions. For example, if managers and harvest contractors know something about the soil moisture regime and drainage capability on the site, they can minimize site damage by locating skid trails and log landings away from potentially wet areas that may not be apparent until the appearance of a prolonged period of wet weather. The Ontario Institute of Pedology (1985) has produced a useful field manual for describing soils that can be used to determine soil depth, soil texture (e.g., sand, loam, clay), soil moisture regime, and soil drainage.

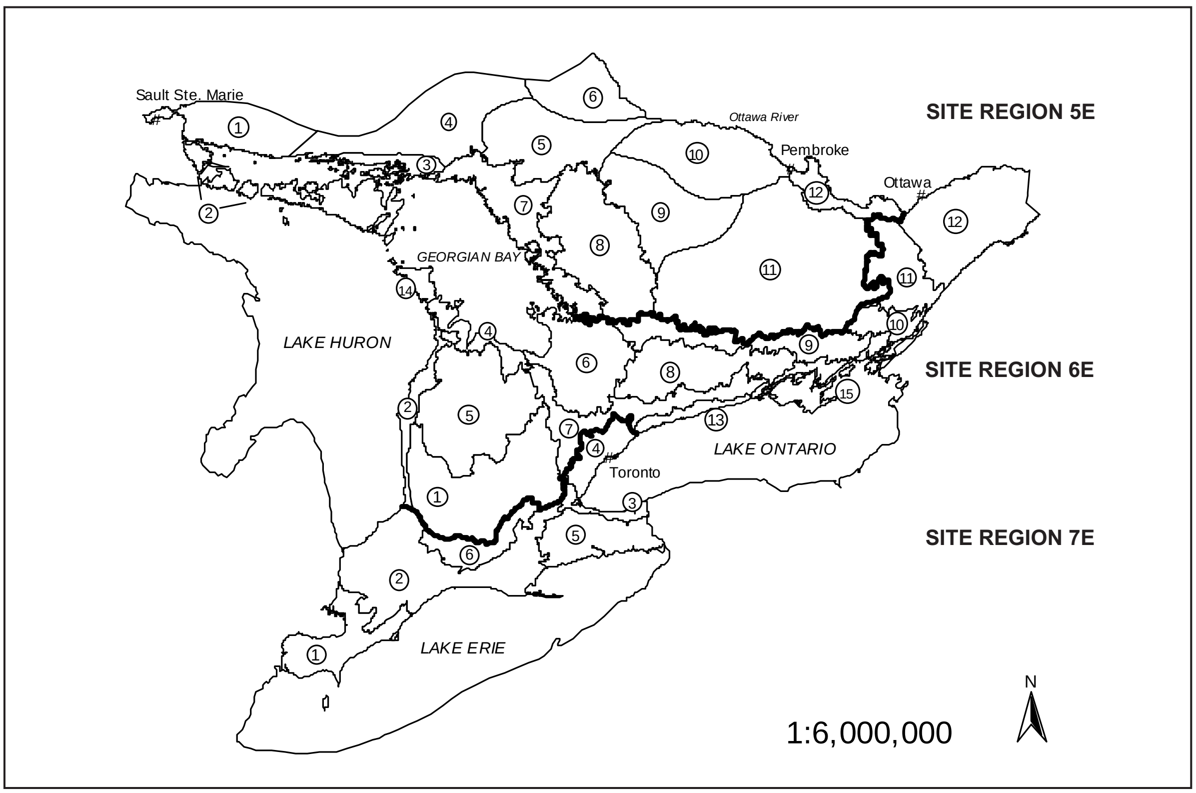
Appendix D reproduces the *Guide to Tree Species Suitability for Site Regions 6E and 7E Using Field Recognizable Soil Properties* (Taylor and Jones 1986). This appendix provides a growth productivity rating for several tree species, across a range of soil texture classes and moisture regimes, based on measurements of DBH and height from hundreds of forest stands across southern Ontario. Ratings are presented in tabular format by species and Site Region.

Managers are encouraged to sample soils during forest stand inventories and then consult these tables to determine which of the species inventoried are actually best suited to the site, determine the most appropriate silvicultural prescriptions, and suggest appropriate species for forest restoration efforts in degraded stands.

Potential site productivity

The interacting effects of latitude, elevation, climate, landform, bedrock geology, and soil texture, depth, and moisture determine the potential of the site to grow trees of various species, size, and quality. In Ontario, the site classification system of Hills (1952) is used to provide a standard description for ranking potential site productivity and species suitability in relation to silvicultural treatment. Hills divided Ontario into Site Regions that are considered to be areas of similar potential biological productivity, based on climate as modified by physiographic landform and proximity to the Great Lakes. Site Regions 6E and 7E comprise southern Ontario (see **Figure 4.1.6)**. A Site District is a subdivision of a Site Region, based on a characteristic pattern of physiographic features that distinguish fairly large areas from each other (Hills 1959). The Site Districts of Site Regions 6E and 7E are shown in **Figure 4.1.6** and described in **Appendix A.** Site Regions 5E and 6E are collectively known as the Great Lakes-St. Lawrence Forest Region and Site Region 7E is known as the Deciduous Forest Region or the Carolinian Life Zone.

Figure 4.1.6: Forest site regions and districts of southern Ontario (from: Hills 1959 and Jalava *et al.* 1997).



4.2 KNOWLEDGE OF FOREST ECOLOGY


E. Boysen

Some knowledge of several aspects of forest ecology such as in natural succession, natural disturbance, and hydrological and nutrient cycling permits a better understanding of stand dynamics and structure. Silvicultural practices will sometimes have to be adapted or modified to protect or to better emulate these processes and their natural patterns of occurrence at both the landscape and stand level. For example, when implementing a group selection prescription, managers and forest workers can vary the size, shape, density, and orientation of created openings, instead of creating unnatural openings of constant shape and size.

The consideration of the following ecological processes will improve the chances of success of future efforts to restore, rehabilitate, or perpetuate certain natural forest types or conditions in southern Ontario over the long-term.

Natural succession

Succession represents the normal growth and development of a forest stand. It is often initiated by some kind of disturbance such as wildfire, or cutting. Usually fast-growing species colonize the site. Over time, as stand and site conditions change, species composition also changes. As crown closure develops, tree growth and competition lead to recognizable patterns of stand development, with species with lesser shade tolerance in the upper layers and species of greater shade tolerance in the lower layers. As mature trees in the overstory die, shade-tolerant mid-canopy trees colonize these newly created gaps. Unless the openings are larger than one canopy height in radius, the succeeding regeneration will remain under some influence of the preceding overstory. These "gap-phase regeneration dynamics" are ecologically significant since the gaps are small enough to be influenced by adjacent overstory vegetation (Runkel and Yetter 1987).

The old-growth stage is achieved when the stand has developed a series of gaps over time that result in a stable balance of trees of different species, sizes, and ages. This stage tends to have greater stability in biomass and productivity than earlier successional stages (Guldin 1996). In reality, few stands attain true old-growth status since the required exclusion of major disturbance events for several hundred years is highly unlikely.

An awareness of the successional process encourages the selection of management activities that better imitate stand development through natural succession. For example, even-aged silvicultural prescriptions designed to encourage regeneration and the development of intolerant and mid-tolerant species are best applied during the earlier stages of natural succession (i.e., between stand initiation and the development of a closed canopy). Uneven-aged silvicultural prescriptions are best applied to stands in the later stages of succession when stand conditions favor the maintenance over time of stand structure, volume production, and continuous forest cover.

In addition, at the regional scale, an understanding of natural succession implies that sustainable forest management should encourage the development of a variety of successional stages at any one time.

Natural disturbances

In southern Ontario, catastrophic natural disturbance events such as severe wildfires that destroy all overstory vegetation and characteristically return succession back to the stand initiation stage now occur very infrequently. However, localized and less severe disturbances (e.g., insect infestations, severe windstorms, tornadoes, microbursts) are more common. Usually much of a stand is destroyed, but regeneration survives beneath scattered overstory and midstory trees. New regeneration and stand structure are more variable in these stands than in those that develop after complete disturbance.

Small-scale disturbances that affect only one to a few trees occur most frequently and are a basic element of stand development. They may add ecological complexity to stands by creating conditions for multiple species and canopy strata (Guldin 1996). But, some disturbances can simplify stands. For example, an over-population of white-tailed deer can consume virtually all seed, seedlings, and saplings of certain species, making species recruitment impossible. Grazing by cattle can have a similar impact in a short period of time. Invasive species such as garlic mustard can have the same effect, through competition with other plant species in the forest (Nuzzo 2000).

In the western Great Lakes region, fire was most important on pine-dominated uplands and in boreal environments, where such disturbance occurred at roughly 100-year intervals (Heinselman *et al*.1973). Large-scale disturbances in hardwood-hemlock forests were largely the result of severe windthrows but intervals were in the order of at least 1000 years (Canham and Loucks 1984). Small, local windthrows were the most common source of disturbance in this region (Frelich and Lorimer 1991), but outbreaks of insect herbivores, disease, and browsing by large mammals also had significant impacts (White and Mladenoff 1994). The pre-settlement forests of southern Ontario probably experienced a similar natural disturbance regime.

The better forest managers understand the ecological conditions resulting from natural disturbances, the more success they will have in implementing silvicultural prescriptions designed to approximate these disturbances. For example, single-tree selection is used to mimic the smallest scale of natural disturbance (i.e., loss of a single tree to disease, lightning, windthrow). When managers realize that these naturally occurring small openings often close before desirable mid-tolerant regeneration can grow into the canopy, they can foster more favorable ecological conditions for growth and development of regeneration by creating several small gaps of sufficient size in the same area.

Group selection is used to approximate intensive, small-scale natural disturbances that create variable-sized, but slightly larger openings within a stand. The resulting site conditions, such as the amount of sunlight reaching the forest floor, encourage the establishment and development of desired regeneration within the group opening. However, forest managers must also understand how bordering trees, the opening size and its configuration, and other factors can affect the ecological conditions within the gap.

Hydrological and nutrient cycling

Proper, unimpaired cycling of water and nutrients is critical to the functioning of ecosystems, therefore it is imperative that the application of any silvicultural prescription has minimal and preferably no adverse effects on these processes. The selection of the most appropriate silvicultural prescription should be determined in part by its ability to sustain and protect if necessary, these processes.

Water is required by all living organisms and hence is a key factor in their occurrence, distribution, and survival. Nutrient cycles are the processes by which elements important to living organisms such as nitrogen, phosphorus, and carbon move through the biotic and abiotic components of an ecosystem. The many small invertebrates and microorganisms that decompose dead material play an especially important role in nutrient cycles because they recycle nutrients that would otherwise not be returned to the soil.

Research in New York State revealed that soils of more urban oak woodlands had higher rates of mineralization of nitrogen (i.e., the conversion of organic forms of nitrogen to inorganic forms such as nitrate) than soils of more rural woodlands (McDonnell *et al.* 1993 as cited in Sauer *et al.* 1998). These researchers suggested that the principle changes brought about by nitrogen deposition may be an increase in the abundance of bacteria in the soil and litter, combined with reductions in fungal and invertebrate populations. In their study, urban forest floor litter also decomposed more quickly than that of countryside forests.

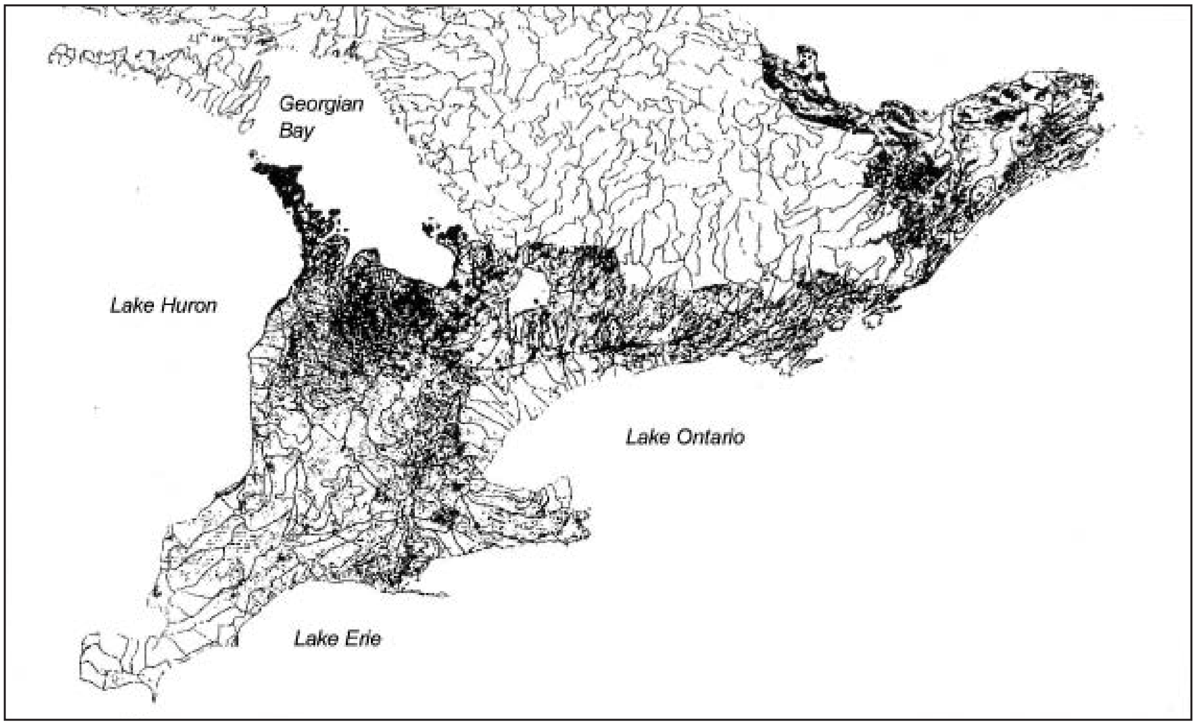
Soil structure is affected by soil nutrient changes too, particularly by a shift from fungal to bacterial dominance. The webby mycelia that comprise the bulk of the fungal component of soil serve to knit together soil particles and bits of organic matter, while the substances secreted by bacteria are slippery and cause soil to slump when it is exposed to rain (Harris *et al.* 1993 as cited *in* Sauer *et al.* 1998).

Although much remains to be learned about hydrological and nutrient cycles, results of these studies imply that forest managers should try to maintain them by protecting important sites such as seepage areas, woodland swamps, springs and creeks; providing natural buffers around them; and prohibiting harvesting and road construction in these areas. When developing prescriptions, they should have forest soils analyzed for their nutrient and pH status, especially in urban areas. Also they will need to consider the potential effects of proposed silvicultural treatments (e.g., increased soil dessication resulting from opening the canopy) on the soil structure and nutrient status.

Human impacts on the forested landscape

In southern Ontario, human activities have modified most, if not all forested landscapes. In parts of southwestern Ontario, the amount and pattern of forest cover, and stand composition and structure no longer even remotely resemble presettlement forests. **Figure 4.2.1** reveals some interesting patterns, including: narrow bands of linear forests in agriculturally-based southwestern Ontario and relatively continuous forest cover in the Bruce Peninsula/Grey County area and Renfrew, Lanark, and Frontenac Counties where poor soils and surficial bedrock impeded early agricultural efforts.

Figure 4.2.1: Forest cover (solid black) in southern Ontario (circa 1985-1991) as mapped from Landsat TM satellite imagery by Ontario Power Generation.



Managers can use their knowledge of some of the historical human impacts on forests to help them to interpret current stand distribution, composition, and structure in this part of the province, and to determine potential stand productivity, based on the past human disturbance of the stand and larger landscape.

Since the time of European settlement, forests in southern Ontario have been cleared for agriculture, logging, and urban development and these activities have had numerous impacts on the amount and distribution of forest cover, stand structure, and species composition.

Amount and distribution of forest cover

Compared to the presettlement era, today in most of southern Ontario forest cover dramatically decreased. For example, in southwestern Ontario, forest cover was once well over 80 %, but is now only 11.3 % (Reid *et al.* 1996). In southeastern Ontario and many parts of the northeastern United States the area of forest cover has actually increased since the 1930s due mostly to the abandonment and subsequent natural regeneration of marginal farmland (McKibbon 1996).

Distribution of forest cover has changed as well. It is likely that the increase in forest fragmentation has had several detrimental effects on native species of plants and animals. Increased isolation of forest patches favors plants better adapted to longer-range seed dispersal. Wide-ranging mammals such as black bear, lynx, and wolf are no longer widespread in this part of the province because there is insufficient forest cover to adequately meet their habitat requirements.

Sometimes the impacts are more insidious as species slowly disappear over time due to altered environmental conditions. For example, many smaller stands may be acting as population "sinks" because they continue to attract nesting forest birds, but may not be large enough to sustain their numbers over the long-term. Breeding birds nest on these sites, but the young are lost to predation or nest parasitism by more common species such as blue jays, grackles, crows, cowbirds, great horned owls, racoons, and domestic cats. Over time, local populations decline as birds continue to breed in these inferior habitats.

The fragmentation of existing forest cover has increased the amount of edge, providing abundant habitat for many species that are already widespread or becoming more common. At the same time, species that require forest interior habitats are declining. As forest edge increases and forest interior size continues to shrink, the more sensitive interior species disappear.

The drier, windier, and brighter microclimate on the edge of forest stands differs markedly from that of the forest interior. As a result, the vegetation structure and composition along the edge is different, being comprised of more xeric, shade-intolerant species. Physical edge effects such as higher diurnal air temperatures, decreases in humidity and wind may extend into a forest stand, along with pesticide, soil, and nitrogen deposition. In addition, exotic species often gain their first foothold in forest edges, from which they can spread farther into the forest, opportunistically seeking out small openings and other disturbed areas such as trails.

Many suburban forestlands are young, the result of recently abandoned farms. Often, they consist of small woodland fragments, unconnected to the larger natural landscape. These small isolated woodlots surrounded by croplands are more likely to suffer severe damage from a windstorm than a larger stand within a matrix of forested cover. Many interior species that are still found in these areas may be in jeopardy in the future because no extensive forest remains, and reproduction may be confined to a few, often invasive and abundant plant species that flourish in these fragments (Sauer *et al*. 1998).

All of these impacts have important consequences for forest managers because they may adversely affect local and regional biodiversity, as well as the regeneration, growth, density, and mortality of trees in the vicinity of forest edges.

Stand structure

Human activities have simplified the physical structure of many forest stands in southern Ontario. A loss of structural diversity in managed stands usually results in reduced biodiversity and abundance of many species. Any silvicultural system that fails to retain large downed logs, cavity and supercanopy trees, standing snags, and several vertical layers of vegetation will adversely affect associated species that depend upon them. Application of recent OMNR guidelines for the retention of these habitats is encouraged and discussed later in **Section 4.4.**

Forest stands that consist of several layers of vegetation (e.g., herbaceous plants, shrubs, understory, midstory, and overstory trees) provide vertical complexity important to many species of birds and insects. Therefore silvicultural systems that encourage this vertical complexity should be widely applied, particularly in larger stands that most likely support significant populations and species, and in stands where such complexity is obviously lacking. For example, harvesting activities such as skidding should minimize damage to herbaceous vegetation, shrubs, and understory trees. Removal of competing vegetation should be conducted with awareness of the wildlife habitat value of less commercially valuable tree species such as ironwood, beech, and basswood and shrubs such as spicebush, serviceberry, and chokecherry.

A certain proportion of stands in late-succession, exhibiting structural diversity and vertical complexity, should be maintained and managed to perpetuate these important ecological conditions. For example, this could be done by managing a certain proportion of forest stands on longer rotations to encourage the development of these conditions. Also the best late-successional stands could be managed for old-growth characteristics because the structural diversity, multi-layered canopies, and scattered gaps of these older forests will eventually support high plant and animal diversity, as well as numerous species of conservation concern.

Activities having negative impacts on stand structure should be controlled. In southern Ontario, grazing cattle in woodlots is a common practice that can lead to soil compaction; loss of herbaceous plants, most notably the spring ephemerals such as trilliums; an abnormal increase in shrubs such as prickly ash and trees such as ironwood; and damage to and reduction of desirable understory regeneration. Missing age classes, a notable lack of seedling and sapling regeneration, and dominance by Virginia spring beauty and yellow dogtooth violet, two wildflowers that can tolerate trampling (Keddy and Drummond 1996), provide clues of past grazing activities.

Management that prevents cattle and other livestock from entering woodlots will help many stands to recover. Sometimes however, more intensive restoration efforts may be required. One method involves driving vertical stakes made from cut branches into compacted ground, as deep as possible in a dense pattern. This permits downward water movement into the root zone and loosens the soil surface as the stakes decompose, thereby increasing soil aeration, and decreasing soil compaction (Sauer *et al*. 1998).

Species composition

Since early European settlement, human landuse and environmental changes have influenced forest species composition. Before European settlement, periodic burning of oak and pine forests limited the domination of red maple. But fire suppression has encouraged the spread of red maple, a species with catholic requirements and the ability to act as both an early and late successional species. It has increased its predominance in the forests of eastern North America by exploiting the conditions that follow forest disturbance, abandonment of agricultural land, and fire suppression in the original forests (Abrams 1998).

During the 1800s, loggers removed once dominant tree species such as hemlock and white pine from many forests throughout the region, largely for navy ship masts (pine) and bark for the tanning industry (hemlock). Further changes occurred during the 1900s, often reflecting local market demand for timber. For example, in many woodlots, the proportion of beech increased because it had no commercial value. Over time, unnaturally high densities of this shade-tolerant species remained to influence the subsequent development of the stands in which they were growing. Certain landuse practices continue to affect tree species composition today. Allowing cattle and other livestock to graze in woodlots has increased the amount of ironwood because cattle do not eat it, preferring instead to graze on numerous other species.

Well-intentioned management programs have also drastically altered the natural species composition of many forest stands in southern Ontario. During the 1970s beech and ironwood were entirely removed from many woodlots due to their poor market value and because they provided unwanted competition for more desirable species (Elliott 1998). Conifer plantations seen today were planted on land that was once forested and later cleared for agriculture. Opportunity now exists to manage these plantations to encourage natural succession to native hardwood forest cover types.

Humans have also introduced several diseases that have led to a loss of once common tree species in southern Ontario such as American chestnut and white elm. Chestnut blight arrived in southwestern Ontario in the early 1920s and within 50 years had virtually eliminated American chestnut from the province. This provincially rare species is now only rarely found, growing on a few drier, sandy sites in southwestern Ontario. Dutch elm disease arrived in the 1920s and subsequently killed a significant portion of the elm populations in Ontario. However some resistant trees remained and many young trees have regenerated. Unfortunately when many of these young trees reach a diameter of 10 to 15 cm and their growth rate slows, they become infected and die.

More recently, other potentially lethal diseases are beginning to infect butternut trees across the province (butternut canker) and flowering dogwood (anthracnose). And beech bark disease and ash decline are affecting the health of many beech and white ash trees.

Forest clearing and the related loss of soil, ground debris, canopy closure, and associated species (e.g., invertebrates, insects, and others); as well as the leveling of pit and mound topography, reduction of downed woody debris, increase in forest fragmentation, and loss of old growth probably have had many other impacts on forest species composition and ecology that may never be fully understood.

Although the effects on forest ecology, caused by loss of tree species or drastic changes in their distribution and abundance, have been little studied, it often requires little intuition to realize that large-scale and/or sudden changes to a forest stand will seriously change the ecosystem. Consequently, landowners and managers are advised to remember that sometimes even their own management decisions and activities can greatly alter stand structure and composition, as well as the course of natural succession.

Here is a common example of such a scenario that can occur in many parts of southern Ontario. Landowners and forest managers may wish to manage stands using silvicultural prescriptions that encourage the reproduction, regeneration, and growth of red oak. This species has high market and wildlife value and aesthetic appeal to many people. However regeneration and growth requirements naturally restrict it to specific sites that are not widespread throughout a region that is dominated mainly by tolerant hardwood forests comprised of species such as sugar maple and beech. Therefore it is probably unwise (and potentially expensive) to convert these stands or portions of these stands to red oak unless this species is already a dominant component of them and/or the site conditions (e.g., dry, sandy soils) are particularly suitable.

Invasive exotic species

An invasive exotic species is a non-native plant or animal that threatens the survival of native species. Their biological characteristics and/or lack of natural control agents (e.g., insect herbivores) provide them with a competitive advantage over the native species with which they become associated. Some of these species should worry landowners and forest managers because they have demonstrated that they can quickly invade a site, proliferate, and then seriously affect the growth of native vegetation (Nuzzo 2000). For example, in a two-year study , the invasive exotic Japanese honeysuckle had a greater negative impact on the height and diameter growth of sycamore than did the native vine, Virginia creeper (Dillenburg *et al.* 1993). Also, once well established, they are often difficult to eradicate. **Table 4.2.1** lists the trees, shrubs, and herbs that most commonly cause problems in the woodlots of southern Ontario.

Due at least in part to this unwanted competition from these exotics, native plant diversity has declined in many stands, particularly those located near urban centers. Some of them (e.g., Norway maple, European and glossy buckthorn, various exotic honeysuckles, garlic mustard) become easily established in these woodlands because these areas provide many of the conditions that favor their introduction: they are often small and fragmented; highly disturbed by roads, and pedestrian and vehicular traffic; and located close to seed sources (e.g., gardens).

Increasing populations of non-native species also alter ecological functions within the forest. For example, a recent study (Whelan and Schmidt 1999) suggests that the decline of songbirds may be linked to increased dominance of forest understories by non-native shrubs. Predation of both robin and thrush nests was higher in the non-native shrubs than in the native shrubs and trees in a 200 ha (500 acre) deciduous woodland preserve near Chicago. At the study site, the non-native honeysuckle shrub had largely replaced the native arrowwood shrub and buckthorn had replaced hawthorn. Birds that nested in non-native shrubs lost more eggs to raccoons and other predators. The researchers speculated that the increased predation was partly due to differences in the physical structure of non-native and native shrubs. For example, buckthorn lacks the sharp thorns of hawthorn, that could deter mammalian predators, and honeysuckle has sturdier branches, that could both help predators climb higher and support nests closer to the ground, where they are more accessible to predators. The researchers also noted a six-fold increase in the number of robins that nested in honeysuckle (from 5 % to more than 30 %), and they speculated that honeysuckle attracts nesting birds because it sometimes leafs out earlier than native shrubs.

Table 4.2.1: Common invasive plants of forested habitats[1] in southern Ontario.

Scientific Name	Common Name
Herbaceous plants	
Aegopodium podagraria	Goutweed
Alliaria petiolata	Garlic Mustard
Chelidonium majus	Celandine*
Hesperis matronalis	Dame's-rocket
Lysimachia nummularia	Moneywort
Trees and shrubs	
Acer negundo	Manitoba Maple
Acer platanoides	Norway Maple
Elaeagnus umbellata	Autumn Olive
Celastrus orbiculatus	Oriental Bittersweet
Cynanchum sp.	Dog-strangling Vine*
Lonicera tatarica	Tartarian Honeysuckle*
Morus alba	White Mulberry*
Populus alba	White Poplar*
Rosa multiflora	Multiflora Rose
Rhamnus cathartica	Common or European Buckthorn
Rhamnus frangula	Glossy Buckthorn
Robinia pseudo-acacia	Black Locust*
Ulmus pumila	Siberian Elm*
Viburnum opulus	European Guelder Rose

[1] Species marked with an asterisk are more common in forest edges.

How to control exotic species

It is often impossible to prevent the introduction of some exotic species. Here are some actions that can reduce the incidence of invasion by these species and sometimes prevent their spread altogether.

- Avoid or minimize ground disturbance (e.g., from road, trail, landing, and ditch construction; clearing of trees and "brush"; all-terrain vehicle (ATV) traffic) since this encourages the establishment of many invasive exotics.
- Do not take equipment (e.g., tractors, skidders) into a woodlot without hosing off all soil that might be harbouring weed seeds.
- Learn to identify the most serious exotics and then regularly monitor the woodlot and adjacent land.
- Remove plants when they first show up in the woodlot or adjacent to it. This may require cooperation among landowners and the municipality. It is much easier to prevent the establishment of these species rather than try to eliminate them once they have become established. See **Table 8.1.4** for recommended control methods for the most important species.
- If large numbers of them are found on the property, get expert advice before attempting to remove them. Certain removal activities may actually cause populations of some of these species to increase.
- Do not deposit brush from shade-tree trimming or removal or garden plant material in or adjacent to woodlots because this material may have viable seeds.

Conclusion

Many of the forests in southern Ontario are unlikely to ever resemble those of the presettlement landscape. Nevertheless, at the site level, landowners and managers who prudently select and apply the most appropriate silvicultural prescriptions, according to accepted guidelines, will help to improve the structure and native species composition of their managed woodlots, as well as help to prevent the spread of exotic species. Collectively, this conscientious management across the larger landscape could prevent further loss and fragmentation of forest cover where these have become serious problems.

Landowners and managers are more likely to realize these changes if they use silvicultural systems that will provide a broad range of appropriate ecological conditions rather than simplify forest ecosystems by reducing forest structure and species composition. At the very least, they should be aware of how their silvicultural prescriptions are likely to affect these fundamental elements in different types of forest stands. For example, a management directive to thin the canopy may be effectively used to stimulate desirable understory regeneration within a large, natural forest stand, but could be a totally inappropriate activity in smaller, remnant woodlands located in a suburban landscape because it tends to encourage invasion by exotic species and/or disproportionately increase the amount of detrimental edge habitat.

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4.3 KNOWLEDGE OF AUTECOLOGY

Autecology refers to the study of the ecology of a single species, including its requirements, tolerances, adaptations to its environment, and responses to environmental changes. It has wider application than the word ‘silvics’ since this branch of ecology is not limited to the study of tree species. Foresters and silvicultural professionals use the word ‘silvics’ to refer only to biological characteristics of trees that affect their growth, reproduction, and responses to changes in their environment.

Resource managers should understand the autecology of target tree species and their principle competitors. Autecology tables for most tree species that occur in the forests of southern Ontario are found in **Appendix B**. Forest managers can use these tables, in conjunction with their knowledge of the site (i.e., information from the site/stand inventory and the ecosite description), to help them develop effective prescriptions. They can use this information to create more natural and favorable site and stand conditions; to promote certain species and/or discourage others; to maintain or improve stand quality; and to reduce the level and impact of unnatural disturbance.

For example, the ecological requirements (e.g., nutrients, amount of shade, moisture regime) of the target species can be compared with site inventory data to determine how well the site currently satisfies these requirements and might continue to do so, under each proposed silvicultural prescription.

Then the biological characteristics of the crop and non-crop species can be examined to determine their respective capacities to become established and develop on a particular site. Knowing something about the reproductive biology of these species will enable managers to choose silvicultural prescription(s) best designed to promote desired species and/or discourage undesirable species. For example, if red oak is the crop species, the aspects of its reproductive biology highlighted in **Table 4.3.1** could prove helpful in designing a silvicultural prescription (e.g., using either the shelterwood or group selection system) to promote its regeneration, as described in the table.

The species tables in **Appendix B** provide a basis for prescribing treatments that meet other silvicultural objectives, besides regeneration. For example, an understanding of how target species will likely respond to proposed silvicultural prescriptions that encourage production of high-quality saw- and veneer logs can be determined. **Appendix B** provides information on a species’ response to release (i.e., by selective thinning treatments). Returning to the red oak example, managers know that oak responds best if the first thinning of trees in the codominant or above-average intermediate crown classes occurs before trees are less than 30-years-old (trees will still respond well to thinning in later years). Therefore, when considering thinning in an even-aged stand dominated by red oak, the first thinning should be timed accordingly.

Table 4.3.1: Autecology of red oak influencing silvicultural prescriptions for regeneration.

Autecological traits of red oak	Application to silvicultural prescription
Sexual reproduction (e.g., acorn production)	
• larger acorn crops are not usually produced until trees are 50-years-old • most mature acorns are shed during September to October • bumper crops of acorns are usually produced on 3-5 year cycles • some trees are inherently better acorn producers than others on the same site • best seed-producing trees have: diameters of 40 - 60 cm DBH; large, healthy crowns exposed to full sunlight; straight boles; and, exhibit faster growth	Tailor silvicultural prescriptions to improve acorn production by: • identifying the better seed-producing trees (i.e., before the first cut in shelterwood, and in areas of the stand where single-tree selection thinning occurs adjacent to future planned group openings) • retaining a mixture of these trees (i.e., after the shelterwood's removal cut and in areas of the stand adjacent to freshly-made group openings) • increasing the exposure of these crowns to sunlight by thinning • making both regeneration cuts (in shelterwood system) and group openings (in group selection) in a good year for acorn production to ensure adequate seed in spite of insect and animal predation • encouraging regeneration of the best identified seed producers
Asexual reproduction (e.g., sprouting)	
• stump sprouting potential and growth of sprouts decreases with parent tree age • red oak is a prolific sprouter to about 60 years of age • red oaks > 50 cm DBH sprout infrequently • stump sprouts from buds at or near the ground are more likely to survive and produce a straight stem of good quality than sprouts originating from higher up near the root collar • height growth of sprouts is much greater than that of true seedlings • heavily shaded advanced reproduction and stressed trees exhibit decreased sprouting ability	Tailor silvicultural prescriptions to compensate for deficiencies in the amount of seedling-origin red oak advanced reproduction by: • enhancing and exploiting the sprouting potential of red oak stumps and seedlings • cutting small trees (< 50 cm DBH) that are removed in the "thinning from below" low to the ground (ideally in snow-less conditions) to encourage sprouting
Seedling light requirements	
• best growth at 30 % of full sunlight	Tailor silvicultural prescriptions to provide optimal light requirements by: • retaining a 60 - 70 % residual crown closure following the regeneration or seed cut when using the shelterwood system • creating a canopy gap diameter size of 1X tree height for south-facing openings and 2X tree height for north-facing openings (see **Table 6.1.10**) when using the group selection system
Response to disturbance and competing species	

• sprouts will originate from buds near the root collar on seedlings that experience complete shoot kill due to environmental conditions (e.g., fire, frost damage)
• sprouting (from cut stems) ability of competitor species (e.g., maples) can affect oak regeneration, but these species are usually unable to sprout following fire
	Tailor silvicultural prescriptions to control competing understory vegetation by:
	• enhancing both the ability of new red oak seedlings to become established and discouraging the growth of competing maple species, for example:
	    • prescribing fire or selective herbicide application to release established red oak seedlings and sprouts
	    • avoiding mechanical cutting that would stimulate sprouting and increase density and vigor of competing maples

Predicting response to disturbance (e.g., from silvicultural treatments) requires some knowledge of forest ecology, especially the autecology of crop and non-crop species, existing site conditions, and potential changes in site conditions resulting from a specific activity or disturbance. For example, to understand the response of crop and non-crop species in a forest stand consisting of tolerant and/or mid-tolerant species that will undergo some partial cutting (e.g., single-tree or group selection), managers should know as much as possible about the following ecological factors.

- Current site/stand conditions that can influence impacts of the disturbance (i.e., cutting) on site and stand (e.g., drainage, soil moisture regime, species composition in the vicinity of the proposed cutting, presence of adjacent seed trees).
- Potential changes in existing site conditions due to the nature, scale, and timing of this disturbance. Potential microclimatic changes provide a good example. Increased sunlight could lead to greater soil and seed desiccation. Increases in air movement and temperature extremes of air, soil surface, and seedbed might have negative impacts on seed germination. Group selection openings or patch cuts in low-lying areas may create a frost pocket where regenerating seedlings can be damaged by late spring frost events. Changes to the microsite that affect the infiltration of water might alter the water table. Changes resulting in exposed mineral soil and organic material, or soil compaction and rutting could change the availability and cycling of essential nutrients.
- Autecological characteristics of crop and non-crop species concerning their response to these changes described above, particularly as they affect the ability of these species to reproduce, regenerate, and compete.

4.4 CONSERVATION OF WILDLIFE HABITAT


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Many species of wildlife depend on forest cover. Some knowledge of the habitat requirements of selected mammals, birds, reptiles, amphibians, and certain guilds of species (e.g., forest songbirds) makes possible the selection of silvicultural prescriptions and management activities that can safeguard significant wildlife habitats in forest stands or at least minimize damage to them. This information can help managers and landowners to:

- identify significant features within a stand, such as a population of a regionally rare plant
- time the implementation of forest activities so as to cause a minimum of disturbance to a habitat
- determine the most critical habitat components that should be maintained for a species (e.g., a movement corridor linking a winter deer yard area to the summer range)
- identify potential silvicultural treatments that could be used to improve or restore a specific wildlife habitat within a stand
- recommend potential mitigation strategies to minimize habitat degradation or loss

Even when wildlife habitat conservation is not a primary management objective, forest managers should try to find out what significant habitats and species might be found in the forest stands under their management and then tailor their prescriptions to avoid harming them. Often OMNR ecologists and biologists, as well as local experts, can provide much of this information.

Although much remains to be learned about the critical habitat requirements of many species, adherence whenever possible to two basic guidelines will help managers to conserve wildlife habitat associated with forested areas.

1. First, silvicultural prescriptions that provide as much continuous forest cover as possible are likely to meet the habitat requirements of a greater number of forest species than prescriptions that increase fragmentation and the amount of forest edge.
2. Second, more conservative and stringent regulations on harvesting (**Section 8.3**) should lead to less disruption of forest ecosystems and retention of more wildlife habitat than lax regulations.

Regional approach

Forest managers and landowners can contribute to wildlife conservation by adopting a larger, regional perspective to all their planning and management activities. Using this approach, the stand to be managed is regarded within the broader landscape context, not in isolation from other stands. Knowledge of the overall landscape (e.g., percent of forest cover, age and distribution of stands, presence of significant species depending on selected forest types, regional wildlife movement) can be incorporated into silvicultural prescriptions to try to maintain a diversity of forest types, at different successional stages, with broad corridors of native vegetation connecting as many of them as possible.

For example, certain songbird species appear to require forest habitats of a minimum size for their long-term survival; once the area of their habitat falls below this minimum size, their populations begin to dwindle due to losses from predation, nest parasitism, and other unknown causes that reduce breeding and nesting success (Freemark 1989; Robinson *et al.* 1995). Unfortunately, in many parts of southern Ontario, remaining forest stands may not be sustaining current populations of these songbirds. Wherever such birds are found, resource managers and landowners should consider not only the effects of their management activities on these birds, but also potential impacts of their decisions on other stands within the region. Furthermore they should also be aware of possible impacts on their stands resulting from the management of adjacent tracts of forest.

Every silvicultural system has at least some negative impacts on the physical environment and wildlife habitat. Therefore, managers should always encourage the strict protection of wildlife habitat features in forest stands with regionally significant conservation value. Many of these areas have already been identified (e.g., Areas of Natural and Scientific Interest (ANSIs), Environmentally Sensitive Areas (ESAs), potential old-growth stands) and management plans should recognize them (i.e., they would be mapped and described) and state clearly that no silvicultural activities should occur in them, unless required for the maintenance of a particular habitat or successional stage. Relatively undisturbed, potential old-growth stands, should be allowed to undergo natural succession because of their value to so many wildlife species, especially numerous species of conservation concern, and their value as benchmarks for scientific research.

Landowners and forest managers can contribute greatly to wildlife habitat conservation at the local level as well. In most parts of southern Ontario, many stands are small, forested islands that are surrounded by croplands, roads, and residential development. But, these habitats are probably incapable of supporting much wildlife over the long-term due to their small size, isolation, greater susceptibility to human impacts, and the adjacent landscape. However managers could consider enhancing larger stands (e.g., those greater than 10 ha) that are situated amid a more natural landscape, by using silvicultural prescriptions to improve forest structure and composition, minimize edge habitat, and where feasible, establish linkages to other forest stands. In addition, managers could work at the local level to restore natural forest cover to suitable sites. They might identify critical areas such as potential linkages among remaining forest stands or gaps within stands, and then allow them to mature or regenerate to forest cover.

Some important forest habitats

The forests of southern Ontario provide several general types of wildlife habitat. These habitat types are described below. Recognizing them can help landowners and forest managers to identify them more easily and then tailor silvicultural prescriptions to protect or minimize damage to them.

Seasonal concentration areas

At certain times of the year, some species and species guilds (e.g., forest songbirds, amphibians) concentrate in certain areas at relatively high densities. Whenever possible, these habitats should be protected because their degradation can result in the loss of high numbers of the animals that depend on them, and local populations of some species could be severely reduced. For example, a pond within a woodlot might provide the only breeding habitat for the majority, if not all of the frogs and salamanders in the stand. Most of these amphibians are unable to move large distances, especially across open areas, to find other breeding ponds. Therefore if local populations of these animals are to be protected, it is essential that management plans identify these areas as significant wildlife habitat, and then ensure that any silvicultural activities at any time of the year will not result in their degradation or loss. Also the plan might state that the implementation of the selected silvicultural prescriptions must not lead to loss of riparian vegetation or corridors for amphibians to move to and from their breeding ponds, or adversely affect the hydrology of the pond and surrounding area.

Guidelines for protection of specific habitats have been developed by the OMNR, and these should be included in forest management plans. Examples of well-known seasonal wildlife concentration habitats that are found in forests, and for which OMNR guidelines have been developed, include winter deer yards (Voigt *et al.* 1997), moose habitat (OMNR 1988), and colonial bird nesting sites such as heronries (Bowman and Siderius 1984).

Other seasonal concentration habitats in southern Ontario are not as well known or studied. Examples of these include amphibian woodland breeding ponds, landbird migration stopover areas, reptile hibernacula, and wild turkey winter-feeding and roosting areas. Several OMNR documents provide habitat management recommendations that could be applied to some of these habitats. For example:

- protection and management of spring, seepages, and intermittent streams could be applied to amphibian woodland breeding ponds and winter wild turkey habitat (Naylor 1998)
- protection and management of conifer stands providing thermal cover for white-tailed deer (Voigt *et al.* 1997) could be applied to wild turkey winter feeding and roosting areas

Some of these habitats that are found in the forests of southern Ontario are briefly described below. See **Table 4.4.1** for additional details, as well as suggestions for how these habitats should be treated while implementing silvicultural prescriptions.

Amphibian woodland breeding ponds

Most amphibians need water to reproduce (e.g., American toad, spring peeper, gray treefrog, wood frog, blue-spotted salamander, red-spotted newt). Swamps, marshes, and weedy shorelines of waterbodies are prime breeding areas. Other important breeding habitat is found within wooded areas, usually in wet depressions and groundwater seepage areas. Critical habitat components include ponds free of predatory fish that, in most years, retain enough shallow, unpolluted water for the duration of the spring breeding season. Emergent and submergent vegetation, both herbaceous and woody, in and around ponds provide sites for calling and egg laying, as well as escape cover. The surrounding forest habitat with an essentially closed canopy provides a shaded, moist understory environment for the pond and its environs that prevents excessive growth of algae and different plant species, and premature drying up of the pond. Abundant downed woody debris supplies cover habitat for more terrestrial amphibians.

Landowners and forest managers can help to protect local populations of amphibians by using only silvicultural prescriptions that will retain the hydrology of the breeding pond (i.e., preserve water level), maintain the key habitat components previously mentioned, and not isolate the breeding pond from summer or winter habitat. Again, the importance of preventing the fragmentation of existing forest cover is evident. Management plans should identify important breeding ponds and clearly state that trees in the vicinity of the pond should not be felled. A no-cut buffer of one tree length (20 to 30 m) will usually suffice but should be evaluated on a site-specific basis.

Landbird migration stopover areas

Large numbers of migrating birds move along the shorelines of the Great Lakes, stopping to rest, feed, and/or wait for inclement weather to pass before attempting to cross open water. They require a variety of relatively undisturbed habitat types, ranging from open fields to mature forests, because each species has different habitat requirements. Forested habitats within five kilometers of the Great Lakes (e.g., especially Lake Erie and Lake Ontario) are particularly important because they provide roosting areas, cover from predators and foul weather, and food for large numbers of many migratory species. Landowners and managers can help to protect important migratory stopover areas by using silvicultural approaches such as partial cutting to maintain forested land, especially along watercourses and in areas where little woodland remains, and to encourage tree species diversity and structural complexity of stands.

Reptile habitat

Many snake species (e.g., garter snake, redbelly snake, brown snake, milk snake, black rat snake) hibernate in woodlands. Hibernacula are often found in areas with cliffs, talus slopes, broken or fissured rock, and burrows that allow snakes and reptiles to get below the frost line. Associated loafing trees and logs that provide shelter in spring and fall also may be important. Additionally, several snakes, including milk snake and black rat snake commonly lay their eggs in the rotting wood of stumps and fallen logs, and seek out these, as well as hollow trees. Thus retention of cavity trees and abundant downed woody material is critical to them. In general, larger stands (i.e., greater than 20 ha) with an interior of mature forest are likely to provide more favorable conditions than small, narrow, or younger woodlots.

Silvicultural prescriptions should recognize the importance of these key habitat features described above, especially downed woody debris. Management plans specify that known hibernacula be protected, and that woody debris greater than a certain size be left as it is, and not be removed or converted to smaller slash. Hollow logs in particular should be left intact, whether standing or fallen. In this way reptile hibernation and gestation sites might be protected and even created. Management of the stand should not result in its fragmentation; although skid trails may be constructed and trees will be removed, the continuous nature of the woodlot should remain intact. This is important to allow snakes to move freely between their summer range and hibernacula. Also prescriptions should try to maintain the relatively stable microclimate of the forest interior by not opening up the overstory canopy too much.

Wild turkey winter range

As winter temperatures decrease and snow accumulates, wild turkeys concentrate in areas with conifer cover. Specific habitat components include mature coniferous trees for roosts (e.g., hemlock, white pine), preferably located next to agricultural fields; sufficient conifer cover to minimize ground accumulation of snow, permitting movement by birds; and spring seeps that reduce snow depths and provide additional food and water.

Silvicultural prescriptions that promote mature conifers, especially hemlocks; protect existing conifer cover, particularly adjacent to agricultural fields and in valleys; and maintain spring seeps can help the overwinter survival of these birds. If forestry activities result in loss of conifer cover, long-term mitigation might result from tree planting designed to enlarge existing areas of cover or reforest recently harvested areas. Over the short-term, planting trees around seeps located in open areas might make them more attractive to turkeys and other wildlife, but should only be undertaken if it is clear that the planted trees will not dry up the seep.

Specialized wildlife habitats

Specialized wildlife habitats include habitats for wildlife with special requirements (e.g., specific nesting, feeding, or seasonal needs). Many specialized habitats are found along the shorelines of waterbodies (e.g., mink and otter feeding and denning sites, moose aquatic feeding and calving areas, and bald eagle and osprey nesting habitat). Key habitat components vary among species (see **Table 4.4.1**) but in general, lack of human disturbance is important. Therefore, where these specialized habitats have been identified or could potentially exist, landowners and managers are urged to refrain from harvest activities during the breeding and nesting seasons. Also buffer zones, to reduce the disturbances (e.g., from machinery noise, habitat loss, presence of people) to these habitats, should be designated and respected. In addition, silvicultural prescriptions that encourage the growth and retention of large trees, especially conifers, along or near shorelines, and downed woody debris, will further enhance the wildlife habitat value of these areas.

Many of the species dependent on specialized habitats, such as raptors (e.g., red-shouldered hawk) and some of the bigger mammals (e.g., fisher, black bear) are known as "area sensitive or dependent species". These animals require larger (at least 200 ha), more continuous tracts of forest, often with a high degree of canopy closure, to sustain their populations (Environment Canada *et al.* 1998).

In areas of southern Ontario, such as the Frontenac Axis and Grey and Bruce Counties, where remaining forest cover is relatively high, landowners and managers can contribute to the conservation of these species (and many others) by maintaining current levels of forest cover and discouraging stand fragmentation. Silvicultural prescriptions could be designed to encourage key features of the habitat for these species such as foraging areas (e.g., by retaining mast-producing trees) and denning habitat for fisher and other mammals (e.g., by encouraging growth and retention of trees larger than 40 cm DBH). In areas such as southwestern Ontario where little forest cover remains, they could adopt a long-term approach and focus on connecting significant forest fragments through reforestation and restoration efforts. Over time, colonization of suitable habitats by these species would become a real possibility.

The OMNR has produced or is in the process of developing guidelines for the protection and management of many of these habitats including raptor nesting habitat, moose calving and aquatic feeding areas, foraging areas with mast species, cavity trees and snags, supercanopy trees, springs and seeps, scattered conifers in hardwood stands, scattered hardwoods in conifer stands, and lake shorelines and other riparian areas. Landowners and managers are encouraged to ask OMNR ecologists for more specific information.

Mast-producing trees

Although red oak is probably the most important hard mast-producing tree in southern Ontario, other important mast trees include white oak, black oak, bur oak, swamp white oak, hickories, beech, black walnut, butternut, American hazelnut, and ironwood. Codominant and dominant trees with large, relatively round and vigorous crowns usually produce the most mast. Many species of wildlife prefer white oak and American beech, but red oak normally produces mast at an earlier age and in larger quantities than white oak. Hickories have more frequent good seed crops than oaks.

Whenever possible, landowners and managers should retain a variety of mast-producing tree species to support a greater diversity of wildlife species and ensure a relatively continuous supply of mast. Naylor (1998, 1999) recommend at least seven to eight good mast producers per hectare at a spacing distance of less than 50 meters between the same species, to ensure successful pollination and seed-set. Additionally, managers might consider creating openings to encourage soft mast-producing species such as cherries, grapes, elderberries, and raspberries.

Cavity trees

Cavities are found in dead trees, snags, and live trees (often culls). A valuable cavity tree for wildlife has the following characteristics:

- a healthy crown and the potential to survive at least through the next cutting cycle
- a cavity that stays dry (i.e., rainwater cannot enter it)
- the potential to provide several benefits for wildlife (e.g., mast production, nest tree, multiple cavities)
- evidence of current use (e.g., fur and claw marks, gnawing around entrance)

Since snag formation and decline of living trees are usually slow processes, intensive timber management over a 20-year period can reduce the amount of cavity habitat to a very low level (Tubbs 1977; Trimble 1963 *in* Anderson and Rice 1993). Therefore thinning operations should not drastically reduce the number of existing or future cavity trees in a stand. Retained cavity trees should not constitute a safety hazard, as defined by the *Occupational Health and Safety Act* (R.S.O. 1990). Major visible defects such as butt rot, large wounds, seams, dead limbs, or dead tops are important indicators of potential cavity and foraging sites (Anderson and Rice 1993).

Current OMNR guidelines (Naylor *et al.* 1996; James 1983 *in* Naylor 1994) recommend retaining:

- six cavity trees per hectare in all shelterwood and seed tree cuts. If six trees cannot be found, the guidelines suggest leaving trees that have a high potential to become cavity trees, for example, those with advanced heart rot
- at least one cavity tree per ha with a minimum 50 cm DBH, with the other cavity trees with DBH measurements between 25 and 50 cm
- cavities in living tree species with dense wood (e.g., maples, oaks) because they will last longer than those in tree species with softer wood (e.g., poplars)
- a uniform distribution of cavity trees throughout the stand (but not within a given hectare)
- cavity trees providing multiple benefits (e.g., cavities and mast)
- a diversity of hardwood and softwood trees with cavities that will benefit a range of wildlife species.

More specifically the order of priority for selection of cavity trees is listed below, as recommended by Naylor *et al.* (1996):

1st Pileated woodpecker roost or nest trees.
2nd Trees with nest cavities of other woodpeckers or natural nest or den cavities for any species.
3rd Trees with escape cavities.
4th Trees with feeding excavations.
5th Trees with the potential to develop cavities.

Stick nest trees

A variety of large bird species (e.g., hawks, owls, ravens, crows) nests in the forests of southern Ontario. Nests are usually located in large-diameter, living trees with forks or crotches that are capable of supporting a big stick nest. Since suitable nest trees are often in short supply, landowners and managers should try to retain all trees containing stick nests. In addition, the retention of at least one forked tree per 10 ha might ensure an adequate number of future nesting sites for these birds. OMNR guidelines (Szuba and Naylor 1998) recommend leaving at least one tree-length reserve around active nests. Additional protective measures may be needed, depending on the species.

Supercanopy

These are living trees whose crowns (i.e., tops) stick up above the main canopy of the forest. They are valuable to large raptors such as bald eagles and ospreys for nesting and perching and may be used by black bears as refuge trees and bedding sites. Managers should keep at least one supercanopy tree (usually > 60 cm DBH) or potential supercanopy tree for every two hectares. These can be the same ones as those identified as "large-diameter" trees if tall enough.

Downed woody debris

Downed woody debris refers to fallen trees, limbs and branches, and their remains, found on the forest floor. This organic material provides important habitat for fungi, reptiles, amphibians, small mammals, invertebrates, and bacteria. As the wood decays, it returns nutrients to the forest soil and creates and maintains the fertile, moist conditions that many tree and herbaceous species need to grow. Some tree species, such as yellow birch and hemlock commonly regenerate on rotting logs and stumps.

Research by Goodburn and Lorimer (1998) found more downed woody debris in old-growth stands (99 m^3/ha) than in managed stands (60m^3/ha). Kurzava and Mladenoff (1999) discovered fewer fruiting bodies of polyporoid and coricoid fungi species per unit area in managed stands than in old-growth stands. Although small - and medium-sized mammalian predators were more abundant in managed stands, amphibians were more common in old-growth stands. Also species composition of ground-dwelling beetles was found to be more sensitive to forest habitat and management regime than was overall abundance or species richness Kurzava and Mladenoff (1999).

Shorelines, springs, and seeps

These areas and their associated riparian vegetation often constitute highly significant wildlife habitat for numerous plants and animals. In addition, they are frequently sensitive environments that could be seriously harmed by various silvicultural activities. Therefore they should be considered for protection, and roads and skid trails should not be established in these areas. If cutting is unavoidable, thinnings should be light with felled trees removed by winching. Also managers should retain at least 70 % canopy closure to maintain current levels of shade and existing water temperatures.

Habitats of species of conservation concern

Species of conservation concern include endangered, threatened, vulnerable, or rare species; species currently experiencing significant population declines in the province; or species of importance to a local region. Currently, in southern Ontario, 82 % of the species provincially listed as vulnerable, threatened, or endangered (often referred to as VTE species), excluding fish, occur on private lands (D. Sutherland and W. Bakowsky, OMNR, personal communication, 1998).

Numerous species of conservation concern are found in the forests of southern Ontario. A few examples are briefly discussed below (see **Table 4.4.1 to 4.4.4**). Landowners and managers can help to conserve them by first determining which species are known to occur or could potentially occur in regional forests. Then they can learn about their specific habitat requirements and how selected silvicultural activities might be used to benefit these species. OMNR district ecologists can provide some of this information. Recovery plans have been written for some of these species and can help forest managers who want to protect or restore their habitat. Copies of recovery plans may be obtained from OMNR district ecologists.

Rare/uncommon tree species and associations

Some forest stands, particularly in southwestern Ontario, support provincially rare, threatened or endangered tree, shrub, and herbaceous species (**Tables 4.4.2 to 4.4.4**). As well, in many municipalities in southern Ontario, there are woodlots comprised of trees, tree associations, and successional stages that are uncommon and/or poorly represented in the surrounding region (**Table 4.4.5**).

Landowners and forest managers can promote the conservation of these significant species and associations in several ways. Their management plans could state that all such tree and shrub species should not be cut and no-cut buffer zones could be designated. In addition, managers could use silvicultural prescriptions promoting the natural regeneration of tree species that are at the edge of their natural range, using these remnant seed tree populations.

Southern flying squirrel

Southern flying squirrels build nests in hollow trees created by heart rot and holes made by woodpeckers. Prime habitat for these animals consists of mature deciduous forests, particularly those comprised of maple, beech, and oak that produce an abundance of foods such as tree seeds, nut crops, and mushrooms. Preferred woodlots are relatively large (i.e., at least 20 ha) and usually have numerous trees over 20 m high with advanced heart rot.

In order to protect the habitat of this species, silvicultural prescriptions should not reduce the size or change the composition of mature deciduous woodlots. Thinning, especially of mast-producing species such as oak and beech, should not significantly reduce food supplies for these animals. Management plans for woodlots supporting these mammals should state that sufficient cavity/nest trees must be retained and that older trees be allowed to age to replace nest trees that will eventually fall down.

Since southern flying squirrels are difficult to identify, any flying squirrel should be assumed to be this species of concern. They can be found by tapping cavity trees, using flashlights after dark to detect their eyeshine, listening for their high-pitched calls, and mist-netting (a permit for netting will be required from the OMNR or the Canadian Wildlife Service).

Woodland raptors

A variety of raptors found in woodlands of southern Ontario are species of conservation concern (e.g., Cooper's hawk, northern goshawk, sharp-shinned hawk, red-shouldered hawk, broad-winged hawk, and barred owl), due largely to forest fragmentation and their dependence on larger tracts of continuous forest cover. These birds also tend to be relatively intolerant of human disturbance, particularly at the nest site.

Silvicultural prescriptions should encourage the recovery of local populations of these species by retaining the area of existing forest cover, avoiding further fragmentation of woodlots, and minimizing disturbance to nesting areas. In addition, management plans should recognize that:

- large trees provide potential nest sites for many of these species
- a large increase in regeneration can make hunting more difficult within the stand for species such as the accipiters, red-shouldered hawk, and barred owl
- sufficient canopy closure is important to many species

- opening woodlots up by heavy thinning could subject rarer red-shouldered hawks to direct competition from red-tailed hawks which can displace this more sensitive species
- downed woody debris provides cover for prey species such as small mammals and amphibians
- barred owls require cavity trees
- many raptors use supercanopy trees for perches and nests
- decadent trees and snags are important habitat features for raptors

<u>Forest interior birds</u>

This guild of birds is also vulnerable to forest fragmentation because most species require larger, continuous forest tracts for long-term survival. Some are also VTE species and found in southern Ontario including: Acadian flycatcher, red-shouldered hawk, cerulean warbler, prothonotary warbler, Louisiana waterthrush, and hooded warbler. Other forest interior birds are considered species of conservation concern, depending on the listing authority, and the status of the birds within a given part of the province.

The habitat requirements of these species are variable and complex. But in general, they tend to avoid forest edges, and prefer to nest in the interior of a stand. Landowners with habitat for species of conservation concern are strongly encouraged to include its maintenance and protection as an objective in a management plan. Also they are advised to seek the advice of OMNR district ecologists and local experts before developing a management plan. Once again, silvicultural prescriptions should discourage forest fragmentation and the creation of edge habitat, and encourage the development of structural diversity within the stand (e.g., downed woody debris, large mature trees, snags). In areas facing severe white-tailed deer browsing pressure, silvicultural practices should discourage foraging by this mammal because it prevents regeneration of the shrub and tree sapling layer, critical habitat for the survival of many birds of the forest interior.

Recent studies from southwestern Ontario (McCracken 1999) suggest that some forest interior bird species, including the endangered Acadian flycatcher, and the wood thrush, veery, scarlet tanager, cerulean warbler, and American redstart prefer to nest in parts of the forest with a high basal area of large-diameter size trees. This finding suggests there may be some advantage to maintaining large- and extra-large sawlog size trees in close proximity to each other as well as the opportunity for future revenue from large veneer-quality trees.

Animal movement corridors

Movement corridors are essential to sustain long-term populations of many wildlife species because they permit animals to move safely across the landscape, between different parts of their habitat and also provide opportunities for the future re-colonization of an area. Many types of habitat (e.g., wetlands, woodlands, old fields, fencerows, creeks, shorelines, unopened road allowances, railroads) function as movement corridors. They are found at both the local and regional scales and often encompass a variety of different terrains.

Forest management plans should identify all known and potential movement corridors. Consultation with OMNR district ecologists and biologists and local experts might help managers to identify significant corridors. Important wildlife habitats might be identified and then corridors linking habitats can be designated. Corridors could be mapped and included within the management plan for the forest.

For example, in parts of southern Ontario where significant snow depth occurs, areas of conifer cover are important for the winter survival of white-tailed deer, numerous small mammals, and wild turkeys. These animals must be able to move safely to this habitat from their summer range. However, many animals prefer to travel through wooded areas to reach them and will not cross large open landscapes. Landowners and managers can use topographical maps and aerial photographs to identify potential corridors and areas of conifer cover in the vicinity of the managed stand.

Landowners and forest managers can contribute to the conservation of animal movement corridors in several ways. First they can ensure that their silvicultural activities will not sever existing links between key habitats both within and outside the management area.

Second, they can ensure that their silvicultural prescriptions do not result in further fragmentation of forest cover, particularly in stands known to provide significant wildlife habitat for forest species (e.g., woodland raptors, area sensitive songbirds, southern flying squirrel, some amphibians). Even within a stand, when large openings are created, some small mammals and amphibians may be reluctant to cross these areas.

Third, they can try to connect, through the restoration of natural forest vegetation, the most ecologically significant, remaining forest stands that were once probably contiguous at an earlier time. In southern Ontario, many of these stands have already been identified (e.g., ANSIs, ESAs). OMNR district ecologists can provide specific information about the conservation value of many of these sites.

Table 4.4.1: Summary of wildlife features or areas, their importance, and suggested forest management treatment.

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
Potentially a consideration in all forest stands			
amphibian breeding ponds	• **areas of standing water used by a variety of frogs, toads, and salamanders during their breeding season** • most amphibians require a source of water to reproduce • these areas are often very important to local populations because they tend to support concentrations of amphibians	• identify potential sites close to summer habitat i.e., the stand to be managed (e.g., shallow, unpolluted water, either temporary or permanent, with the former holding water long enough for larvae to develop into adults; emergent and submergent vegetation, logs and shoreline shrubs for calling and egg-laying; surrounding woodland providing closed canopy offering a shaded, moist understory and an abundance of downed woody debris for cover while amphibians are on terrestrial habitats) • ensure that all forestry activities in the vicinity of the breeding pond do not change the moisture regime of the pond or the adjacent woodland (e.g., no major decrease in shade in surrounding forest or loss of water) • activities should not fragment existing forests in a way that reduces the habitat for adults of certain species after they leave the breeding pond • activities should not sever the travel corridors from breeding ponds to summer habitat • logging roads should be at least 20 m from potential amphibian breeding ponds	• OMNR offices for general location of some important sites; species habitat requirements; a source of contact with experts • the Natural Heritage Information Centre (NHIC) maintains database on location of reptiles and amphibians and includes location of known concentration areas • Canadian Wildlife Service, Burlington for contact with volunteers participating in Amphibian Road Call Counts and the Backyard Amphibian Survey who know locally important sites • Bird Studies Canada for contact with local volunteers participating in Marsh Monitoring Program who know locally important sites • other sources including consultants and naturalist club reports, and atlas results, may provide some important site locations and species descriptions. They may be found at OMNR, NHIC, Conservation Authority, Ontario Power Generation, municipality offices

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References

<u>cavities</u>	• **cavities are hollows in living or dead trees that usually develop following injury to the trees or excavation by woodpeckers and allow wildlife access to their interior**
	• at least 50 species require cavities for nesting, denning, roosting and/or feeding
	• cavities made by primary excavators (e.g., woodpeckers) are used by other species (e.g., owls, squirrels), thus increasing the wildlife diversity of the area
	• the protection from exposure that cavities provide can be critical to winter survival of some species (e.g., gray and flying squirrels)
	• in southwestern Ontario, the southern flying squirrel, a vulnerable species, is dependent on cavities
		• try to retain cavity trees that will last at least 20 years (e.g., cavities in living tolerant hardwoods are likely to last longer than cavities in intolerant species such as poplar or white birch)
		• retain large-diameter cavity trees (usually at least 45 cm DBH) because they provide potential cavities for both large and small animals
		• retain cavity trees providing multiple wildlife benefits (e.g., oaks, hickories, beech, black cherry, basswood, ironwood provide mast for a wide variety of wildlife; conifer cavity trees provide protection from cold, snow, predators and will eventually form long-lasting standing dead trees)
		• give preference to trees with cavities in the upper portion of the bole
		• adhere to existing guidelines (e.g., retain at least 6 cavity trees of at least 25 cm DBH per hectare in all harvest blocks; retain at least 1 cavity tree/ha that is at least 40 cm DBH)
		• Select cavity trees to leave using the following order of priority:
		  ◦ Pileated woodpecker roost or nest trees
		  ◦ Trees with nest cavities of other woodpeckers or natural nest or den cavities
		  ◦ Trees with feeding excavations
		  ◦ Trees with the potential to develop cavities
			• *Extension Note:* "Cavity Trees are Refuges for Wildlife"
			• forest management guidelines for the provision of pileated woodpecker habitat, Appendix 2: Criteria for Selecting Cavity Trees for Retention (Naylor *et al.* 1996).

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
downed woody debris (DWD)	• **DWD refers to fallen trees, limbs and branches, and their remains found on the forest floor** • provides important habitat for a variety of wildlife (e.g., invertebrates, salamanders, ruffed grouse, wildflowers, mosses, ferns, fungi, bacteria) • increases wildlife diversity of the stand • provides insulation from heat and cold • absorbs and retains moisture (even during drought) • their decomposition adds organic matter and nutrients to the soil, improving tree growth • provides required seedbed for regeneration of some species (e.g., yellow birch, hemlock and cedar)	• identify areas in the stand with high DWD that should be retained within the management plan • ensure skid trails are efficiently laid out to minimize skidding disturbance • use narrow trails instead of roads • remove branches and tree tops from harvested trees at the felling site rather than at a landing • do not remove down organic debris • do not disturb large rotting logs, hollow logs • whenever feasible, limit damage to organic debris and soil by using non-mechanical means to haul timber	*Extension Notes:* • "Restoring Old-growth Features to Managed Forests in Southern Ontario" • "Careful Harvesting with Cut and Skid Crews"

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
<u>stands supporting birds vulnerable to forest fragmentation (i.e., forest interior or area sensitive species)</u>	• **forest interior refers to the sheltered, secluded environment away from the influence of forest edges and open habitats; generally at least 100 m in from the edge of the forest** • provide shelter, nesting habitat, food, resting areas, refuge from predators • help to maintain local populations of birds dependent on these habitats which are in short supply in the fragmented forests of southern Ontario • serve to maintain the biodiversity of the area or region • help to maintain forest health by supporting birds that provide important ecological services (e.g., pest control, seed dispersal, pruning, fertilization)	• identify important stands (e.g., often the largest, contiguous forest stands in the area; larger stands with few internal openings and few irregular edges) • where they exist, maintain blocks of forest of at least 30 ha, and preferably with 50 ha or more in closed canopy condition (e.g., at least 70 % canopy closure) through single-tree selection • ensure that forestry activities do not reduce the overall area of the forest, or increase fragmentation or edge habitat • avoid forestry activities during the breeding season (Mar. 20 to Aug. 31) • consider reducing the harvesting of trees within the forest interior; protection of forest interior for wildlife habitat (e.g., as an AOC or core protected area) is a management objective • minimize removal of larger trees and snags • leave some clumps of larger diameter trees • carefully weigh potentially conflicting objectives for creating gaps (e.g., silvicultural objective of regenerating less tolerant species) vs. wildife objective of maintaining forest interior bird habitat • maintain dense stands of trees at edges of woodlots and minimize the number of exit laneways particularly on vulnerable edges (e.g., southwest-facing)	• aerial photographs are especially helpful for determining the area of contiguous closed-canopy forest cover • OMNR Forest Resource Inventory (FRI) maps (scale 1:15,840), although outdated, indicate the dominant tree species, percent composition of the stand, and approximate age of the forest stands; latter information particularly helpful because older deciduous stands with abundant and diverse forest structure tend to be preferred by these species • local birders may know location of premier woodlands for interior sensitive species, the location of some forest nesting raptors • Bird Studies Canada webpage www.bsc-eoc.org lists bird species of conservation concern by municipality • *Extension Note:* "Conserving the Forest Interior—A Threatened Wildlife Habitat" • *Factsheet:* "Conserving Woodland Birds in Southern Ontario" (available from Bird Studies Canada 1-888-448-2473)

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
<u>clumps of large-diameter trees</u> of either medium sawlog (38-48 cm DBH) or large sawlog (50 – 60 cm), and extra-large sawlog (>62 cm) size	• some forest interior species prefer nesting in the vicinity of large-diameter trees (e.g., Acadian flycatcher, wood thrush, veery, scarlet tanager, cerulean warbler, American redstart)	• where possible, retain clumps of larger diameter trees, especially if the stand is within a core forest area that provides more than 40 ha of forest interior • where possible, use tree marking and single-tree selection cutting to encourage the development of some clumps of larger trees especially within the forest interior • avoid forestry activities during the breeding season (Mar. 20 to Aug. 31)	• Bird Studies Canada/OMNR/CWS study in the South Walsingham forest tract (McCracken 1999)
<u>marten and fisher habitat</u> (e.g., denning and home range habitat)	• **member of the weasel family having large home ranges and a preference for larger, older forests** • in general, provision of habitat for fisher supplies at least some of the habitat required by various other species that are also associated with larger, mature and old-growth forests, cavity trees, and downed woody debris • provide some income for trappers	OMNR's guidelines for marten wildlife habitat should also benefit fisher: • at the regional scale, determine whether sufficient marten habitat exists or has the potential to develop, given current land use patterns, policy initiatives • set preliminary objectives for marten populations and habitat if sufficient habitat exists in the region • at the regional scale and over the long-term, aim for at least 30 % of the forest area in mature and old-growth conditions • partial harvesting can occur in as much as 30 % of the core habitat area if it retains 50 % of the original conifer basal area and a canopy closure of at least 50 % (hardwoods and conifers) • avoid fragmenting existing forest stands	• *Wild Furbearer and Conservation Management in Ontario (*Novak *et al.* 1987) • *Forest Management Guidelines for the Provision of Marten Habitat* (Watt *et al.* 1996) • *Development and Validation of a Habitat Suitability Index Model for the American Marten in Central Ontario* (Naylor *et al.* 1994)

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
		• maintain wooded corridors/links between core areas of suitable habitat (i.e., unharvested areas) with no gaps or gaps of less than 1 km • identify sites with potential to support marten and fisher • maintain 10 to 20 % of the forest with potential to support marten and fisher (i.e., large enough, at maturity- spruce, fir, or cedar dominated or mixed forest condition) • on appropriate sites, use selective silvicultural techniques to encourage an overstory greater than 40 % spruce, fir, or cedar with a canopy closure of conifers of at least 50 % and average height of 15 m • to provide resting sites and dens, as well as habitat for prey species, employ harvesting practices that retain at least 6 dead or declining trees per hectare, with at least 2 of these exceeding 30 cm DBH, as well as logs, stumps and other downed woody debris on the site (e.g., leave slash at the stump, use site preparation techniques that minimize slash removal and alignment)	

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
mast trees (e.g., beech, oaks, hickories, basswood, black cherry, ironwood, butternut, black walnut, honey locust, tulip tree, red mulberry, eastern flowering dogwood, American chestnut)	• trees (and shrubs) producing edible fruits (e.g., acorns, beech nuts, berries) • at least 75 species of wildlife eat the fruits, berries, nuts (known as mast) produced by a variety of trees and shrubs • availability of mast can influence weight gain, reproductive rate, and even survival of some animals • red mulberry, serviceberries, pin cherry and alternate-leaved dogwood produce berries in midsummer that are eaten by adult breeding birds at a time when they require extra energy • mast-producing species increase the wildlife diversity within the stand and surrounding area	• retain a minimum of 8 trees/ha of mast species (no more than 50 m apart) with DBH > 25 cm • prefer to retain healthy, mature trees with large, rounded, vigorous crowns because these trees generally produce more mast • retain numerous oak trees with 40-65 cm DBH because such trees produce the heaviest acorn crops • on appropriate sites, encourage the growth and regeneration of mast producers through tree marking and silvicultural activities • however, consider the regeneration requirements of these species, especially if they are mature or old (e.g., many mast species are intermediate in light tolerance and will require larger openings and sometimes seedbed treatment to encourage regeneration) • refer to autecology tables (**Appendix B**) for specific species' regeneration requirements	• stand inventory will determine distribution and average size of mast species in stand • topographical maps and aerial photographs can indicate features like ridges and rock barrens that often have oaks and berry-producing shrubs, respectively • tree marking certification course study notes: wildlife habitat concerns (Naylor 1999) • *Extension Note:* "Restoring Old-growth Features to Managed Forests in Southern Ontario"

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References

old growth or mature forest	• **refers to stands in the region or planning unit that are considerably older than most other stands (hence age in years is relative, but frequently at least 80-100 years old), often with numerous big trees and canopy gaps, large amount of downed woody debris**
	• provides benchmarks for research and education
	• supports associated species that are now uncommon or rare due to limited old growth forest habitat
	• contributes to habitat and community diversity at a regional scale
	• provides habitat for some species with specialized habitat requirements
	• meets specialized timber requirements (e.g., high-value veneer or specialty wood products)
	• meets spiritual and aesthetic needs of some people
		• identify prospective sites at both the stand and landscape level (e.g., old growth potential exists; minimal or no human disturbance; potential to manage stands for old growth characteristics is possible and desirable)
		• plan to encourage or maintain some oldgrowth stands at both the stand and landscape levels
		• consider preserving some exemplary stands (i.e., no management, no cutting)
		• initiate old growth stands by extending rotation periods and using the recommended diameter distribution and stocking given in **Table 6.1.6**
		• refrain from removing dead wood from potential oldgrowth stands
		• consider treating stands adjacent to potential sites with an old-growth prescription **(Table 6.1.6 or 6.1.7)** that leaves higher basal area in larger diameter trees to manage these stands for oldgrowth characteristics
			• *Woodland Heritage of Southern Ontario* (Larson *et al.* 1999) documents 34 southern Ontario woodlands with some old-growth characteristics
			• OMNR FRI maps, although outdated, will indicate potential woodlands containing larger, older trees that are likely to provide large-diameter trees, snags, and abundant downed woody debris
			• *Extension Notes:*
			    • "Restoring Old-growth Features to Managed Forests in Southern Ontario"
			    • "The Old-growth Forests of Southern Ontario"

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
reptile or bat winter hibernacula	• **caves and mines (bats); subterranean areas below the frost line (reptiles) with openings to above ground where these animals can safely hibernate during the winter months** • hibernacula may be critical to long-term survival of local or even regional populations • some hibernacula may be used by several species of snakes or bats • in some areas hibernacula (especially for bats, large snakes near northern limit of their range) may be scarce and therefore very important to their users • some hibernacula may support large numbers of bats or snakes due to their scarcity	• no forestry operations within 200 m of entrance to a bat hibernaculum • no forestry operations within 50 m of reptile hibernacula • in order to maintain movement corridors for snakes, only single-tree selection is recommended for use in forests with known hibernacula • operations should not disrupt surface microhabitats such as vegetation, downed woody debris, rocks and talus, or movement to summer range • overstory canopy closure should not be opened up too much	• little available information on location of bat hibernacula • Natural Heritage Information Centre for locations of hibernacula • Ontario Ministry of Northern Development and Mines for locations of abandoned mines that may provide potentially significant bat hibernacula • some members of outdoor recreation clubs (e.g., Sierra Club) explore caves and may know location of hibernacula • University Biology Departments for bat experts who may know locations of important sites and habitat requirements

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
seeps, springs, streams (including intermittent)	• **areas where water is found at or very near the surface of the ground throughout all or much of the year** • these areas provide important habitat for many aquatic and terrestrial species • rare or uncommon species are often found in these areas (e.g., ginseng and numerous other plants; two-lined salamander) • they can serve to maintain or influence the hydrological regime of adjacent areas such as wetlands • seepage areas are often important overwintering habitat for frogs	• retain high canopy-closure (e.g., at least 75 %) in the vicinity of these areas • avoid marking trees that will likely be felled across these areas • avoid locating roads or landings in these areas • avoid crossing these areas with heavy equipment (**Section 8.3**)	• topographical maps and aerial photographs indicate headwaters of streams where springs may be found • County soil survey reports and maps describe local physical characteristics such as soils, landforms, and drainage patterns that can narrow the search for springs and seeps • local naturalists and landowners may know of some locations • Municipalities may have surveyed drainage systems and headwater areas may be mapped • many Conservation Authorities monitor stream flows and consequently may know locations of springs and seeps • OMNR staff and local anglers may know location of some springs/seeps that can affect the distribution of sportfish such as brook trout or plants often associated with seeps (e.g., ginseng)
snags	• **snags are standing dead trees** • barred owls, pileated woodpeckers, hairy woodpeckers, silver-haired bats, raccoons, some snakes and amphibians, many insects, fungi and other life forms rely on snags for food and shelter • when snags fall over, they add to the level of decomposing wood on the ground • some raptors use snags during hunting to observe the surrounding area • during sunny weather, some birds perch on snags to dry plumage, warm themselves	• leave as many snags as possible, preferably exhibiting a variety of different stages of decay • retain at least 4 smaller (< 50 cm DBH) and 1 larger (> 50 cm DBH) for a total of 5 snags/ha • in stands where few natural snags occur, consider girdling (by removing a strip of bark from around a tree) to allow some trees to become snags	• *Extension Note:* "Restoring Old-growth Features to Managed Forests in Southern Ontario"

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
stick nests	• **stick nests are platforms made predominantly of twigs, sticks, and/or small branches usually located in or just below the crown of a tree, in primary or secondary forks or on a sturdy lateral limb** • stick nests are primarily built by raptors (hawks, eagles, owls, falcons) for nesting • their maintenance can help to offset declines of some raptor species • these nests can increase the wildlife diversity of an area because they may be used by a variety of animals including barred owls, great horned owls, long-eared owls, merlins, ravens, crows, and squirrels • different species will use each other's nests	• retain all trees with stick nests, whether nests are active or inactive • if stick nest is active, retain surrounding trees within a radius of 150 m • for active red-shouldered or Cooper's hawk nests, maintain an additional 20 ha of suitable nesting habitat located to encompass adjacent suitable habitat and satellite nests • do not schedule harvesting during Mar. 1 - July 31 breeding season • only selection harvesting, designed to retain at least 70% canopy closure, should be used • avoid locating roads or landings within 200 m of stick nests	• *Forest Raptors and their Nests in Central Ontario: A Guide to Stick Nests and Their Users* (Szuba and Naylor 1998) • OMNR/Bird Studies Canada Ontario Birds at Risk Program (OBAR) runs the red-shouldered hawk survey; volunteers monitor many stands in southwest and central Ontario and the records of nest locations can help to locate sites important to these area sensitive species; these forest stands are often equally important to forest interior or area sensitive species as well • local landowners and naturalists may know the location of some raptor nests or stands supporting raptors

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
supercanopy trees	• **living trees that stick up above the main canopy of a stand** • used by large raptors such as bald eagles and • used by black bears as refuge trees and bedding sites • may be important as a potential seed source for surrounding stand	• retain some supercanopy trees in all cuts • retention of at least 1 supercanopy pine or hemlock of at least 50 cm DBH (or preferably a cluster of at least 3 trees) per 4 ha of cut can enhance habitat suitability for bears • try to retain at least 1 supercanopy tree per 16 ha around eagle nests • give special protection to pines, hemlocks or spruces near wetlands--try to retain at least 1 supercanopy tree (or preferably a cluster of at least 3 trees) per 500 m of shoreline	• tree marking certification course study notes: wildlife habitat concerns (Naylor 1999) • *Extension Note:* "Restoring Old-growth Features to Managed Forests in Southern Ontario"

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
vulnerable, threatened or endangered (VTE) understory vegetation (**Tables 4.4.2** to **4.4.4**)	• several understory herbaceous species (e.g., ginseng) have low populations due to any number of factors including forest fragmentation • to ensure that tree harvesting operations do not contribute to further declines of these species careful harvesting practices (**Section 8.3**) must be employed	• minimize soil disturbance from skidding of logs and equipment movement by carefully logging in winter, frozen-ground conditions • winter timing of tree harvesting does not negatively affect the underground root meristems of herbaceous species (Reader 1987) • to avoid damage or loss, small patches of provincially rare plants (e.g., ginseng, Hart's tongue fern) should be well-marked and a buffer area left between them and subsequently laid out logging roads and skid trails; this practice will avoid disturbing the forest floor in these locations (Reader 1987) • prevent introduction of invasive exotic species by requiring that logging equipment be steamer/pressure-washed before entering the site	• Natural Heritage Information Center (NHIC) database (http://www.mnr.gov.on.ca/MNR/nhic/queries/detquery.html) maintains element occurrences for VTE species, and although one cannot determine the name of the species, existence of an occurrence in the geographic area in the vicinity of the stand will indicate that caution may be required • local naturalists may be aware of locations for populations of VTE understory vegetation species in local forest stands

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
winter deer yards	• **areas of forested habitat where concentrations of white-tailed deer spend much of their time during the winter months** • provide protection from cold, snow, predators • permit increased mobility and ease of access to feeding areas • of value to other wildlife during winter (e.g., wild turkey)	• ideally 10 - 30 % of total deer range should be conifer dominated stands, with a minimum conifer component of 70 % and crown closure of 60 % • in stand thinning operations, aim for clumping (i.e., 3-5 trees with interlocking crowns) rather than uniform spacing of residual conifers because the former approach provides better thermal cover and snow interception • retain at least 80 % conifer canopy closure on knobs and knolls (prime deer bedding areas) • ideally a minimum of 40 % of deer range should be second growth or regenerating stands, occurring within 800 m of conifer shelter	• *Forest Management Guidelines for the Provision of White-tailed Deer Habitat* (Voigt *et al.* 1997). • OMNR for location and relative importance of many yards • in southwestern Ontario, deer do not winter in yards

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
Potentially of concern in forest stands with a conifer component			
<u>conifer patches within a predominantly hardwood/mixed stand</u>	• provides important thermal protection during winter for deer, moose, numerous small mammals, birds, wild turkeys and raptors • adds to the wildlife diversity of an area/stand by providing habitat for some species commonly associated with conifer forests • serves as natural seed source for regeneration of conifers species such as white pine or hemlock that historically were more widespread	• generally, only remove conifers when they compete with very high quality hardwoods • retain long-lived conifers such as hemlock, white pine, white spruce, and white cedar • where there are 10 or fewer conifers/ha (<= 2 m^2 BA/ha), retain at least 5 conifers/ha • where there are at least 10 conifers/ha (> 2m^2 BA/ha), retain at least 10 conifers/ha • retain trees at least 25 cm DBH, but preferably those of at least 40 cm DBH • for deer in hardwood stands, where possible, retain clumps of 3 to 5 conifers, at least 10 m tall, with interlocking crowns (ideally at a spacing of 30 to 60 m apart) • retain trees with high vigor and low risk unless retained to meet cavity tree objectives • retain trees in clumps of 3 or more because they are especially valuable to wildlife • on appropriate sites, mark and use silvicultural activities to encourage the regeneration of conifers	• tree marking certification course study notes: wildlife habitat concerns (Naylor 1999) • *Extension Note:* "Restoring Old-growth Features to Managed Forests in Southern Ontario"

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
raptor winter roosting areas (patches of conifers)	• **areas where concentrations of raptors sleep or rest for long periods during the winter months** • important for overwintering survival • mature coniferous trees provide thermal protection and concealment, and protection from winter storms • important to many other species of wildlife	• identify potential areas (e.g., existing coniferous patches, in woods adjacent to open fields where birds are regularly seen hunting in winter) • retain conifers (clumps and single trees) • consider planting conifers inside woodlands adjacent to open fields used by hunting raptors	• OMNR; local birders and area residents for location of some areas
wild turkey winter roosting and feeding areas (patches of conifers)	• **areas where concentrations of wild turkeys sleep, rest or feed during the winter months** • important for overwintering survival • mature coniferous trees provide thermal protection and concealment • protection from winter storms • permit movement by turkeys when snow conditions restrict movement in other areas • important to many other species of wildlife	• identify potential areas (e.g., existing coniferous patches, particularly those in valleylands or on lower slopes with southern exposure/seeps) • encourage development of mature trees, especially hemlock and white pine (e. g., by longer rotations) • to provide immediate cover and future roosts, consider planting conifers around suitable seepage areas where planted trees will not dry up the seep	• OMNR; local birders and area residents for location of some areas • guidelines for wild turkey habitat (Reid 1991).

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
Potentially of concern in lowland forests or forest/wetland complexes			
colonial bird nesting sites ⇒ heronries	• **areas of numerous standing trees (living or dead), usually in wetlands or along shorelines, providing undisturbed nesting habitat for seasonal concentrations of herons** • due to the colonial nature of the birds, loss of some heronries can result in the loss of many birds • in some areas, sites assume greater importance because they may be in limited supply	• identify all sites within the vicinity of the forest stand to be managed • no construction or forestry activities should be conducted within 1 km of a site during the nesting season (Mar. 1- Aug. 31) • normal operations could be permitted beyond 300 m from Sept. 1- Feb. 28 • dead trees should not be removed from the heronry • buffer width will vary depending on sensitivity of birds, local site conditions, and adjacent land use; normally such buffers would range from 100 to 300 m • forestry activities (e.g., logging road construction) should not reduce the area of individual wetland or result in changes to normal water level fluctuations or degradation of water quality in the marsh	• OMNR wetland evaluations identify colonial nest sites (e.g., black terns, heronries) if they were observed at time of wetland evaluation • guidelines for heronry protection (Bowman and Siderius 1984)

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
colonial bird breeding sites ⇒ birds of marshes	• **areas found in or adjacent to marshes providing essential food, cover, and nesting habitat for seasonal concentrations of species that nest colonially** • provide important breeding habitat for many species, including numerous rare species • often provides other important habitats (e.g., foraging, cover) • important to many wildlife species	• identify all sites within the vicinity of the forest stand to be managed • no construction or forestry activities should be conducted within 200 m of a site during the breeding season (Mar. 1- Aug. 31) • normal operations could be permitted beyond 100 m from Sept. 1- Feb. 28 • protection of larger wetlands (e.g., at least 100 ha) is important for area sensitive species and maintenance of long-term populations • forestry activities (e.g., logging road construction) should not reduce the area of individual wetland or result in changes to normal water-level fluctuations or degradation of water quality in the marsh	• OMNR for location of regionally and locally significant sites • OMNR wetland evaluations identify locally significant areas • Canadian Wildlife Service for location of regionally and provincially significant sites; species habitat requirements; species of conservation concern; source of several potentially helpful publications • Ontario Nest Records Scheme (ONAR); Royal Ontario Museum database provides information on breeding distribution, nest locations for 283 species • Ducks Unlimited Canada for location of important local sites; species habitat requirements; restoration of waterfowl nesting habitat • local birders for location of some locally important areas; location of some nesting species of conservation concern
Potentially of concern in forest stands associated with shorelines			
bald eagle wintering areas (shorelines)	• **undisturbed areas of large trees providing shelter and unobstructed view, located near productive (fish) water bodies remaining open during all or most of the winter months** • important for the recovery of this endangered species • provide protective cover within a reasonable distance from important winter feeding areas • provide hunting perches	• identify potential areas (e.g., abundant supply of undisturbed mature trees and distributed evenly along shorelines near areas of open water and fish) • retain most, if not all, mature or tall trees and snags in the vicinity of this habitat that provide an unobstructed view and easy access from all sides • no logging during winter months within 1 km of these areas	• OMNR; local birders and area residents for location of some areas

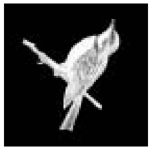


Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
mink and otter foraging and denning sites	• **relatively undisturbed shoreline areas with abundant downed woody debris and shrubs, with adjacent coniferous or mixed forest cover and a productive littoral zone; in addition, for otters- nearshore habitats containing relatively large and productive fish populations** • provide undisturbed sites for resting, escaping predators, protection from inclement weather, and bearing and raising young	• identify potential sites in the vicinity of the stand to be managed • retain at least a 10 m width of shoreline vegetation, including downed woody debris • forestry activities should not disrupt normal water- level fluctuations	These sites are difficult to find but the following sources will provide assistance: • aerial photographs can help to locate prime areas--undisturbed shorelines with abundant vegetation and downed woody debris (e.g., dead falls, large logs) • OMNR for contact with local trappers for information on locations of potentially important shorelines • OMNR wetland evaluations record observations and signs of these mammals (e.g., tracks, scat) as well as presence in other years, through interviews with local trappers • *Wild Furbearer and Conservation Management in Ontario* (Novak *et al.* 1987)
turtle-nesting areas (shoreline areas)	• **areas adjacent to waterbodies and wetlands supporting seasonal concentrations of nesting turtles** • better sites permit egg-laying females to dig out nest, provide good exposure to sun, and allow faster development of eggs • these sites may be very important to local populations in some areas where sand or gravel is in limited supply	• forestry activities should not disrupt turtle-nesting areas such as shorelines of wetlands, lakes, and rivers • do not build logging roads that separate water from backshore areas as they may increase the incidence of road-killed turtles	• OMNR for contact with local trappers for information on locations of potentially important shorelines • OMNR wetland evaluations record observations and signs of these mammals (e.g., tracks, scat) as well as presence in other years, through interviews with local trappers • local residents may know some areas

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
Potentially of concern in parts of southern Ontario that intercept with moose range			
<u>moose winter habitat</u> (moose guidelines, while included, have limited relevance to southern Ontario forests)	• **areas of dense coniferous cover and less snow accumulation supporting concentrations of moose during winter months** • areas improve overwintering survival by reducing energy lost through movement and wind chill • can be very important to survival of pregnant females	• manage for coniferous stand of at least 4 ha that is surrounded by adjacent forested land with an understory stocked with browse for animals • try to enlarge area of smaller existing conifers stands • encourage growth of clumps of conifers to at least 6 m high and 60 percent canopy closure • prefer hemlock, balsam fir, and white spruce because of their superior ability to intercept snow • prefer habitat with some south-facing slopes and open areas where moose can move to on sunny days to absorb the radiant energy • do not locate logging roads near this habitat, if they will be used in winter • generally try to provide sufficient conifer forest and patches of conifers within hardwood forests to support number of moose in the planning area based on OMNR biologist estimates	• OMNR for possible locations of some sites • tree marking certification course study notes: wildlife habitat concerns (Naylor 1997) • timber management guidelines for the provision of moose habitat (OMNR 1988) • *Late winter habitat selection by moose in the northern Great Lakes-St. Lawrence Forest* • (Bellhouse *et al.* 1993)

Table 4.4.1: *continued*

Wildlife Feature or Area	Importance	Suggested Treatment	Sources of Information or References
moose aquatic feeding areas (moose guidelines, while included, have limited relevance to southern Ontario forests)	• **undisturbed areas with abundant aquatic plants that are used by moose during June and July** • aquatic feeding areas provides large amounts of aquatic plants high in sodium, required by moose in June and July for antler development, lactation, and basic neurophysiological functions	• identify potential sites in vicinity of stand to be managed (e.g., abundance of preferred aquatic plants such as pondweeds, yellow water-lily, water-milfoil, others; located adjacent to conifer stand) • ensure that forestry activities have no adverse impacts on associated shoreline vegetation (conifer cover), water-level fluctuation, or water quality and clarity • provide buffer zone with width depending on local site conditions, adjacent land use, importance of site to moose; normally will range from 50 to 150 m for aquatic areas	• OMNR for location of some important aquatic feeding areas and description of such habitats; moose habitat requirements; contact with knowledgeable local residents/cottagers • aerial photographs can help to identify sections of creeks and bays with high potential as aquatic feeding areas • timber management guidelines for the provision of moose habitat (OMNR 1988) • guidelines for assessment of moose aquatic feeding areas (Ranta 1998)
moose calving areas (moose guidelines, while included, have limited relevance to southern Ontario forests)	• **undisturbed areas where moose bear their young** • may be used by moose for many years	• identify potential sites in vicinity of stand to be managed (e.g., undisturbed islands or peninsulas, shorelines less than 100 m from open water; elevated) • forestry activities should not occur in the vicinity of calving sites (mid-May) • logging roads should not be located near known calving areas	• timber management guidelines for the provision of moose habitat (OMNR. 1988) • aerial photographs can help to identify undisturbed islands or peninsulas, shorelines less than 100 m from open water; elevated with high potential as calving areas

Table 4.4.2: Summary of rare and uncommon tree species in southern Ontario: status and distribution.

Scientific Name	Common Name	NHIC Status[1]	COSEWIC (National)[2]	COSSARO (Ontario)[2]	Site Region	
					6E	7E
Acer nigrum	Black Maple	S4			X	X
Aesculus glabra	Ohio Buckeye	S1				X
Betula lenta[3]	Cherry Birch, Sweet Birch	S1				X
Betula populifolia	Gray Birch	S5			X	
Carya laciniosa	Big Shellbark Hickory	S3				X
Carya glabra	Sweet Pignut Hickory	S3				X
Castanea dentata	American Chestnut	S3	thr			X
Celtis occidentalis	Hackberry	S4			X	X
Cercis canadensis	Redbud	SX				X
Crataegus spp.[4]	Hawthorn (several species)	SH-S3				X
Fraxinus profunda	Pumpkin Ash	S2				X
Fraxinus quadrangulata	Blue Ash	S3	thr	vul		X
Gleditsia triacanthos[3]	Honey Locust	S2				X
Gymnocladus dioicus	Kentucky Coffee Tree	S2	thr	thr		X
Juglans nigra	Black Walnut	S4			X	X
Liriodendron tulipifera	Tulip Tree	S4				X
Magnolia acuminata	Cucumber Tree	S2	end	end		X
Morus rubra[5]	Red Mulberry	S2	end			X
Nyssa sylvatica[3]	Black Gum	S3				X
Picea rubens	Red Spruce	S4			X	
Pinus rigida	Pitch Pine	S2S3			X	
Platanus occidentalis	Sycamore, Plane Tree	S4			X	X
Ptelea trifoliata	Hoptree	S3	vul			X
Quercus bicolor	Swamp White Oak	S4			X	X
Quercus ellipsoidalis	Hill's Oak (Northern Pin Oak)	S3				X
Quercus muhlenbergii	Chinquapin Oak	S4			X	X
Quercus palustris	Pin Oak	S3				X
Quercus shumardii	Shumard Oak	S3	vul	vul		X
Quercus velutina	Black Oak	S4			X	X
Salix nigra	Black Willow	S4?			X	X
Sassafras albidum	Sassafras	S4				X

[1](S1) - extremely rare, usually 5 or fewer occurrences in Ontario; (S2) - very rare, usually between 6-20 occurrences; in Ontario, or few remaining hectares; (S3) – rare to uncommon in Ontario, usually between 21-100 occurrences, may have fewer occurrences, but with some extensive examples remaining; (S4) – apparently secure in Ontario (but rare in much of southern Ontario); SH – historically known from Ontario but not verified recently; Note: combinations of ranks indicate that information is insufficient to accurately assign a single rank

[2]end = endangered, thr = threatened, vul = vulnerable; status report prepared for all species with COSEWIC status

[3]MNR status report has been prepared but has not been approved by COSEWIC or COSSARO

[4]approximately 15 "species" ranging from SH to S3, but most species difficult to identify

[5]recovery plan in preparation

Table 4.4.3: Summary of rare and uncommon shrub and woody vine species in southern Ontario: status and distribution.

Scientific Name	Common Name	NHIC Status[1]	COSEWIC (National)[2]	COSSARO (Ontario)[2]	Site Region	
					6E	7E
Amelanchier amabalis	Juneberry	S2S3			X	X
Asimina triloba[4]	Pawpaw	S3				*X*
Campsis radicans	Trumpet Creeper	S2				X
Ceanothus americanus	New Jersey Tea	S4			X	X
Ceanothus herbaceus	Narrow-leaved New Jersey Tea	S4			X	X
Celtis tenuifolia	Dwarf Hackberry	S2	vul	vul	X	X
Chimaphila maculata	Spotted Wintergreen	S1	end			X
Cornus drummondii	Rough-leaved Dogwood	S4				X
Cornus florida	Flowering Dogwood	S3?				X
Corylus americana[4]	American Hazel	S5			X	X
Crataegus douglasii	Douglas' Hawthorn	S4?			X	
Euonymus atropurpurea	Burning Bush	S3				X
Hamamelis virginiana[4]	Witch-hazel	S5			X	X
Hudsonia tomentosa	Woolly Beach-heath	S2-S3			X	X
Hypericum kalmianum	Kalm's St. John's-wort	S4			X	X
Hypericum prolificum	Shrubby St. John's-wort	S2				X
Gaylussacia baccata	Black Huckleberry	S4			X	X
Lindera benzoin[4]	Spicebush	S5			X	X
Malus coronaria	Wild Crabapple	S4				X
Myrica pensylvanica	Bayberry	S1				X
Prunus americana	Wild plum	S4				X
Quercus ilicifolia	Bear Oak	S1			X	
Quercus prinoides[3]	Dwarf Chinquapin Oak	S2				X
Rhododendron canadense	Rhodora	S1			X	
Rhus copallina	Shining Sumac	S3-S4			X	X
Rhus vernix	Poison Sumach	S4			X	X
Rosa carolina	Pasture Rose	S4				X
Rosa setigera	Prairie Rose	S3	vul	vul	X	X
Rubus flagellaris	Northern Dewberry	S4			X	X
Rubus parviflorus	White-flowering Raspberry	S4			X	
Rubus setosus	Bristly Blackberry	S4?			X	X
Smilax hispida	Bristly Greenbrier	S4			X	X
Smilax rotundifolia	Round-leaved Greenbrier	S2	thr	vul		X
Staphylea trifoliata	Bladder-nut	S4			X	X
Vaccinium corymbosum	High-bush Blueberry	S4			X	X
Vaccinium pallidum	Dryland Blueberry	S4			X	X
Vaccinium stamineum	Deerberry	S1	thr		X	X
Viburnum recognitum	Southern Arrowwood	S4			X	X
Vitis aestivalis	Summer Grape	S4				X
Vitis labrusca	Fox Grape	S1			X	X
Vitis vulpina	Frost Grape	S1				X

[1]S1 - extremely rare, usually 5 or fewer occurrences in Ontario; S2 - very rare, usually between 6-20 occurrences in Ontario; S3 - rare in Ontario, usually between 21-100 occurrences in Ontario; S4 - uncommon to locally common and apparently secure in Ontario (but rare in much of southern Ontario); S5 – demonstrably secure in Ontario but may be rare in some regions; SH – historically known from Ontario but not verified recently; SX – apparently extirpated from Ontario
[2]end = endangered; thr = threatened; vul = vulnerable; status report prepared for all COSEWIC designated species
[3]MNR status report has been prepared but not approved by COSEWIC or COSSARO
[4]rare throughout most of Site Region 6E

Table 4.4.4: Summary of some[1] rare and uncommon herbaceous plant species of southern Ontario forests and woodlands: status and distribution.

Scientific Name	Common Name	NHIC Status[2]	COSEWIC (National)[3]	COSSARO (Ontario)[3]	Site Region	
					6E	7E
Agrimonia parviflora	Swamp Agrimony	S3				X
Aletris farinosa	Colic Root	S2	thr	thr		X
Allium cernuum	Nodding Onion	S2				X
Anemonella thalictroides	Rue-anemone	S3			X	X
Aplectrum hyemale	Putty-root	S2			X	X
Arisaema dracontium	Green Dragon	S3	vul	vul		X
Asclepias verticillata	Whorled Milkweed	S2			X	X
Asclepias viridiflora	Green Milkweed	S2			X	X
Asplenium scolopendrium	Hart's-tongue Fern	S3			X	X
Aster divaricatus	White Wood Aster	S1	thr			X
Aster prenanthoides	Crooked-stem Aster	S2	vul	vul		X
Aster schreberi	Schreber's Aster	S2				X
Aster shortii	Short's Aster	S2				X
Astragalus neglectus	Cooper's Milk Vetch	S3			X	X
Aureolaria pedicularia	Fern-leaved False Foxglove	S3				X
Baptisia tinctoria	Yellow Wild Indigo	S2				X
Botrychium lanceolatum	Narrow Triangle Moonwort	S3			X	X
Botrychium oneidense	Blunt-lobed Grapefern	S3			X	X
Botrychium rugulosum	Rugulose Grapefern	S2			X	X
Camassia scilloides	Wild Hyacinth	S2	vul			X
Carex careyana	Carey's Wood Sedge	S2				X
Carex davisii	Awned Graceful Sedge	S2				X
Carex gracilescens	Slender Wood Sedge	S3				X
Carex hirsutella	Hairy Green Sedge	S3				X
Carex jamesii	Grass Sedge	S3				X
Carex muskingumensis	Swamp Oval Sedge	S2				X
Carex seorsa	Swamp Star Sedge	S2				X
Carex squarrosa	Narrow-leaved Cattail Sedge	S2				X
Carex swanii	Downy Green Sedge	S3				X
Carex virescens	Slender Green Sedge	S3				X
Chaerophyllum procumbens	Spreading Chervil	S2				X
Chenopodium standleyanum	Woodland Goosefoot	S2				X
Cimicifuga racemosa	Black Cohosh	S2				X
Conioselinum chinense	Hemlock-parsley	S3				X
Corallorhiza odontorhiza	Autumn Coral-root	S2			X	X
Corydalis flavula	Yellow Corydalis	S2				X
Cypripedium arietinum	Ram's-head Lady's-slipper	S3			X	X
Cystopteris laurentiana	Laurentian Bladder Fern	S2S3			X	
Cystopteris protrusa	Lowland Brittle Fern	S2				X
Desmodium canescens	Hairy Tick-trefoil	S2				X
Desmodium cuspidatum	Bracted Tick-trefoil	S3			X	X
Desmodium rotundifolium	Round-leaved Tick-trefoil	S2			X	X
Erigenia bulbosa	Harbinger-of-spring	S3				X
Eupatorium purpureum	Purple-jointed Joe Pye Weed	S3				X
Frasera caroliniensis	American Columbo	S1	vul	vul		X
Galium pilosum	Hairy Bedstraw	S3			X	X
Geum vernum	Spring Avens	S3				X
Gymnocarpium robertianum	Limestone Oak Fern	S2			X	
Heuchera americana	Rock Geranium	S2				X
Hibiscus moscheutos	Swamp Rose Mallow	S3	vul		X	X
Hieracium paniculatum	Panicled Hawkweed	S2			X	X
Hieracium venosum	Rattlesnake Hawkweed	S2			X	X
Hybanthus concolor	Green Violet	S2			X	X
Hydrastis canadensis	Golden Seal	S2	thr	thr	X	X

Table 4.4.4: *continued*

Scientific Name	Common Name	NHIC Status[2]	COSEWIC (National)[3]	COSSARO (Ontario)[3]	Site Region	
					6E	7E
Hydrophyllum appendiculatum	Appendaged Waterleaf	S2				X
Isopyrum biternatum	False Rue-anemone	S2	vul	vul		X
Isotria medeoloides	Small Whorled Pogonia	S1	end	end		X
Isotria verticillata	Large Whorled Pogonia	S1	end	end		X
Kriga biflora	Two-flowered Cynthia	S2				X
Lactuca floridana	Woodland Blue Lettuce	S2				X
Linum virginianum	Slender Yellow Flax	S2				X
Liparis liliifolia	Purple Twayblade	S2	end	thr	X	X
Listera australis	Southern Twayblade	S2			X	
Lithospermum latifolium	Broad-leaved Puccoon	S3				X
Lupinus perennis	Wild Lupine	S3			X	X
Lycopus rubellus	Stalked Water Horehound	S2				X
Mertensia virginica	Bluebells	S3				X
Mimulus alatus	Winged Monkey Flower	S2				X
Oxytropis rigidor	Stiff Cowbane	S2				X
Panax quinquefolium	American Ginseng	S3	end	thr	X	X
Panicum clandestinum	Broadleaf Panic-grass	S2				X
Panicum dichotomum	Forked Panic-grass	S2			X	X
Peltandra virginica	Arrow Arum	S2			X	X
Phegopteris hexagonoptera	Broad Beech Fern	S3	vul	vul	X	X
Plantago cordata	Heart-leaved Plantain	S1	end	end		X
Platanthera macrophylla	Large Round-leaved Orchid	S2			X	
Poa languida	Weak Bluegrass	S3			X	X
Poa sylvestris	Woodland Bluegrass	S2				X
Polygonum arifolium	Halbard-leaved Tear-thumb	S3			X	X
Pterospora andromedea	Giant Pinedrops	S2			X	X
Sanicula canadensis var. grandis	Long-styled Canadian Snakeroot	S2				X
Smilax ecirrata	Upright Carrion-flower	S3?				X
Smilax illinoensis	Illinois Carrion-flower	S2?				X
Solidago arguta	Sharp-leaved Goldenrod	S3			X	X
Stylophorum diphyllum	Wood Poppy	S1	end	end		X
Tephrosia virginiana	Goat's Rue	S1	thr			X
Thalictrum revolutum	Waxy Meadow-rue	S2				X
Thaspium trifoliatum	Meadow Parsnip	S2				X
Tradescantia ohiensis	Ohio Spiderwort	S2				X
Trillium flexipes	Drooping Trillium	S1	end			X
Triphora trianthophora	Nodding Pogonia	S1	thr			X
Verbesina alternifolia	Wingstem	S2S3				X
Veronia gigantica	Giant Ironweed	S1S2				X
Veronia missurica	Missouri Ironweed	S1S3				X
Veronicastrum virginicum	Culver's-root	S2				X
Vicia caroliniana	Wood Vetch	S2			X	X
Viola palmata	Palmate Violet	S2				X
Viola striata	Cream Violet	S3				X
Woodsia obtusa	Blunt-lobed Woodsia	S1	thr		X	

[1]this is a partial list only; for the most part, only S2 and S3 species have been included; for a complete current listing of Ontario's rare plant species contact the NHIC (www.mnr.gov.on.ca/MNR/nhic/nhic)

[2]S1 - extremely rare, usually 5 or fewer occurrences in Ontario; S2 - very rare, usually between 6-20 occurrences in Ontario S3 - rare in Ontario, usually between 21-100 occurrences in Ontario;S4 - uncommon to locally common and apparently secure in Ontario (but rare in much of southern Ontario);S5 - very common and demonstrably obscure in Ontario (but rare in one or more of the site regions of southern Ontario)

[3]end = endangered; thr = threatened; vul = vulnerable. Species for which a COSEWIC status is given have a status report

Table 4.4.5: Summary of rare forest types in southern Ontario and their status.

Forest Type	Status[1]	Comments
ELC Community Class: Forest		
ELC Community Series: Deciduous Forest		
Dry-Fresh Oak Deciduous Forest Ecosite:		
Dry-Fresh Black Oak Deciduous Forest Type	S3	may not be found in Site Region 6E
Dry-Fresh Mixed Oak Deciduous Forest Type	S3S4	
Dry-Fresh-Oak-Maple-Hickory Deciduous Forest Ecosite:		
Dry-Fresh Oak-Hickory Deciduous Forest Type	S3S4	
Dry-Fresh Hickory Deciduous Forest Type	S3S4	
Dry-Fresh Deciduous Forest Ecosite:		
Dry-Fresh Hackberry Deciduous Forest Type	S2	occurs on calcareous sites; not found in Site Region 6E
Fresh-Moist Lowland Deciduous Forest Ecosite:		
Fresh-Moist Black Walnut Lowland Deciduous Forest Type	S2S3	not found in Site Region 6E
Fresh-Moist Black Maple Lowland Deciduous Forest Type	S3	on dry sites and river terraces
Dry Oak- Pine Mixed Forest Ecosite:		
Dry Oak- Pitch Pine Mixed Forest Type	S1	not found in Site Region 7E; Pitch Pine stands declining due to fire suppression
Dry Chinquapin Oak- Pine Mixed Forest Type	S2	not found in Site Region 6E
ELC Community Class: Swamp		
ELC Community Series: Coniferous Swamp		
White Pine-Hemlock Mineral Coniferous Swamp Ecosite:		
White Pine Mineral Coniferous Swamp Type	S2	areas where flooding duration is short—substrate aerated by early to mid-summer
ELC Community Series: Deciduous Swamp:		
Oak Mineral Deciduous Swamp Ecosite:		
Swamp White Oak Mineral Deciduous Swamp Type	S2S3	areas where flooding duration is short—substrate aerated by early to mid-summer
Bur Oak Mineral Deciduous Swamp Type	S3	areas where flooding duration is short—substrate aerated by early to mid-summer
Pin Oak Mineral Deciduous Swamp Type	S2S3	areas where flooding duration is short—substrate aerated by early to mid-summer

1 S1 extremely rare in Ontario, usually 5 or fewer occurrences or very few remaining hectares; S2 very rare in Ontario, usually between 6 and 20 occurrences, or few remaining hectares; S3 rare to uncommon in Ontario, usually between 21-100 occurrences, may have fewer occurrences, but with some extensive examples remaining; S4 apparently secure in Ontario

Section 5
Assessing Stand and Site Conditions

INTRODUCTION

Sustainable forest management depends on the accurate assessment of site and stand conditions at both local and regional levels, using the best available information. This section outlines the essential components required to inventory and conduct an analysis of stand stocking, structure, and quality so that appropriate silvicultural options presented in **Section 6** can be thoughtfully evaluated.

5.1 INVENTORY

by David Bland and Silvia Strobl

M. Rosen

A forest inventory measures a sample of trees in the stand to determine the density, distribution, volume, and age and size classes present. It estimates the quality and species composition of the overall stand. It also describes other important values of the stand such as the provision of wildlife habitat and the maintenance of important ecological functions (e.g., hydrologic and nutrient cycles). Managers and landowners use this information to develop short- and long-term management objectives and the most suitable silvicultural treatments that will be used to achieve them.

This guide does not provide an extensive description of each stage of an inventory, but a brief summary of the important steps is provided in **Appendix C.**

Describing site conditions

The inventory should also describe site conditions. The Ontario government has developed a common framework for collecting, organizing, analyzing, and reporting ecological information. This framework is called the Provincial Ecological Land Classification. It is intended to describe the variety of ecosystem types across the province.

Ecological Land Classification (ELC)

The OMNR Southern Region Ecological Land Classification (ELC) program has described over 80 wetland and terrestrial forest vegetation types (Lee *et al.* 1998). This preliminary community classification system has six different organizational levels:

1. The first level, the "Site Region" provides the broadest and most general description of the landscape. For this guide, southern Ontario is considered to consist of two Site Regions: 6E and 7E. See **Figure 4.1.6** and **Appendix A** for a map and descriptions of these Site Regions, respectively.
2. The second level classifies communities into three "Systems": aquatic, wetland, and terrestrial systems. Upland areas, where the water table is normally below the soil surface, comprise the terrestrial system. Areas where water levels fluctuate and are under 2 m in depth comprise the wetland system.
3. The third level, the "Community Series I" describes various communities such as forests, swamps, savannas according to their respective patterns of dominant species, substrate type, geology, microclimate, and other ecological factors.
4. The fourth level, "Community Series II", describes communities that can normally be recognized on aerial photographs or from a combination of maps, aerial photograph interpretation, and other remote sensing techniques. Classification relies mainly on vegetation structure (e.g., percent cover of shrubs and trees) and vegetation type (e.g., deciduous, coniferous, mixed).
5. The fifth level of the hierarchy is the "Ecosite". The type of bedrock; soil depth, texture, and moisture regime; hydrology; drainage; nutrient regime; and vegetation structure and species composition are all used to define and identify different ecosites.

6. The "Vegetation Type" is the sixth and finest level of resolution in this community classification system. It represents recurring vegetation patterns observed on the landscape, based only on plant species composition. Normally, "Vegetation Types" include the names of dominant plant species of the community, based on relative abundance.

By using the calculations of percent representation of the dominant tree species in a stand, ecosites can be determined based on the data collected during the stand inventory. To encourage those working with land classification to use the same terms, landowners and managers are urged to use the ELC to describe their forest stands. This will encourage those working with land classification to use the same terms to describe sites that occur on the relatively same parent material, with the same soil and hydrology, and consistently recurring association of species.

The ELC descriptions incorporate terminology developed by the Ontario Institute of Pedology (OIP) to describe soil texture, moisture, and drainage. Landowners and managers are advised to become familiar with the various descriptive terms. These terms and their derivation are defined in the *Field Manual for Describing Soils* (Ontario Institute of Pedology 1985). Soil texture classes are based on the relative proportion of three particle size classes found within a soil sample (i.e., sand, silt, and clay particles). Soil moisture regime represents the seasonal available moisture supply for plant growth. Soil drainage classes represent how quickly water percolates through substrates by gravitational flow.

Managers are encouraged to sample soils during forest stand inventories and then consult **Appendix D** to determine which of the inventoried species are actually best suited to the site. This appendix, reproduces the *Guide to Tree Species Suitability for Site Regions 6E and 7E Using Field Recognizable Soil Properties* (Taylor and Jones 1986). It provides a growth productivity rating for several tree species, across a range of soil texture classes and moisture regimes, based on measurements of DBH and height from hundreds of forest stands across southern Ontario. Ratings are presented in tabular format by species and Site Region.

Forests cover types and their equivalent ELC ecosites

This guide uses more traditional names of the dominant forest cover types of southern Ontario instead of ELC ecosites because the ELC system is being refined and there may be future changes to their nomenclature and community descriptions. However, forest managers working with individual stands should become familiar with the ELC forest ecosites and vegetation types. Adoption of this classification system can help them to:

- describe in a consistent manner some important site conditions (e.g., soil texture, moisture regime, common understory vegetation)
- predict some of the history of the site (e.g., based on existing species associations, past disturbance)
- predict potentially serious plant competitors for desired tree species on a given site
- identify potential rare tree associations or presence of rare plant species
- provide further information about the distribution of different forest types and associations in southern Ontario
- in the future, predict responses to a particular silvicultural prescriptions, based on observed responses to the same prescription on similar ecosites (provided that stands are monitored).

Table 5.1.1 relates more traditional forest cover types to similar ecosites described by the ELC. Examples of silvicultural prescriptions for these forest types are presented in **Section 6.** Information presented in ***A Silvicultural Guide to Managing Southern Ontario Forests*** is most applicable to the seven generalized forest cover types described in **Table 5.1.2**. This guide will not provide specific silvicultural prescription information for plantations but this information is available elsewhere.

Differentiating swamp and forest communities

According to the ELC, in Terrestrial Systems the water table is rarely or only briefly above the substrate surface and the depth of accumulated organic matter is less than 40 cm. Standing water covers no more than 20 % of the area, wetland plant species comprise less than 50 % of the total plant species cover, and the moisture regime derived by using the OIP manual (1985) is typically less than five.

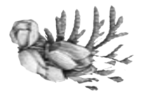
Wetland Systems are characterized by a water table that is seasonally or permanently at or above the substrate surface. The depth of accumulated organic matter is greater than 40 cm. Standing water covers more than 20 % of the site, wetland plant species comprise more than 50 % of the total plant species cover, and the moisture regime derived by using the OIP manual (1985) is five or more.

Silvicultural management of forested swamps can be difficult due to the often challenging site conditions (e.g., presence of water and water-saturated soils) and existence of important conservation and natural heritage values (e.g., protection of local hydrology, provision of significant wildlife habitat, presence of rare species) that should be protected. **Box 6.3.1** lists questions that managers and landowners should answer prior to deciding whether to manage lowland hardwood forests and swamps for timber production. Affirmative answers to all or most of these questions would tend to indicate that such stands be left unmanaged and retained for their non-commercial importance.

Table 5.1.1: Cross-reference of ELC community series and ecosites to more general forest cover types used in this guide.

ELC Levels	Ecosite	ELC Code	Forest Cover Type
Terrestrial System			
Forest Community Class			
Community Series			
Coniferous Forest	Dry-Fresh Pine	FOC1	Pines
	Dry-Fresh Cedar	FOC2	Cedar
	Fresh-Moist Hemlock	FOC3	Hemlock
	Fresh-Moist White Cedar	FOC4	Cedar
Mixed Forest	Dry Oak-Pine	FOM1	Upland Oaks
	Dry-Fresh White Pine-Maple-Oak	FOM2	Upland Oaks
	Dry-Fresh Hardwood-Hemlock	FOM3	Upland Tolerant Hardwood
	Dry-Fresh White Cedar	FOM4	Cedar
	Dry-Fresh White Birch-Poplar-Conifer	FOM5	Early Successional Hardwoods
	Fresh-Moist Hemlock	FOM6	Hemlock
	Fresh-Moist White Cedar-Hardwood	FOM7	Cedar
	Fresh-Moist Poplar-White Birch	FOM8	Early Successional Hardwoods
Deciduous Forest	Dry-Fresh Oak	FOD1	Upland Oaks
	Dry-Fresh Oak-Maple-Hickory	FOD2	Upland Oaks
	Dry Fresh Poplar-White Birch	FOD3	Early Successional Hardwoods
	Dry-Fresh Deciduous Forest	FOD4	Upland Tolerant Hardwood
	Dry-Fresh Sugar Maple	FOD5	Upland Tolerant Hardwood
	Fresh-Moist Sugar Maple	FOD6	Upland Tolerant Hardwood or Lowland Hardwoods and Swamps
	Fresh-Moist Lowland Deciduous Forest	FOD7	Lowland Hardwoods and Swamps
	Fresh-Moist Poplar-Sassafras	FOD8	Early Successional Hardwoods
	Fresh-Moist Oak-Maple-Hickory	FOD9	Lowland Hardwoods and Swamps
Wetland System			
Swamp Community Class			
Community Series			
Coniferous Swamp	White Cedar Mineral	SWC1	Cedar
	White Pine – Hemlock Mineral	SWC2	Pines / Hemlock
	White Cedar Organic	SWC3	Cedar
	Tamarack – Black Spruce Organic	SWC4	
Deciduous Swamp	Oak Mineral	SWD1	Lowland Hardwoods and Swamps
	Ash Mineral	SWD2	Lowland Hardwoods and Swamps
	Maple Mineral	SWD3	Lowland Hardwoods and Swamps
	Mineral	SWD4	Lowland Hardwoods and Swamps
	Ash Organic	SWD5	Lowland Hardwoods and Swamps
	Maple Organic	SWD6	Lowland Hardwoods and Swamps
	Birch – Poplar Organic	SWD7	Lowland Hardwoods and Swamps
Mixed Swamp	White Cedar Mineral	SWM1	Cedar
	Maple Mineral	SWM2	Lowland Hardwoods and Swamps
	Birch – Poplar Mineral	SWM3	Lowland Hardwoods and Swamps
	White Cedar Organic	SWM4	Cedar
	Maple Organic	SWM5	Lowland Hardwoods and Swamps
	Birch – Poplar Organic	SWM6	Lowland Hardwoods and Swamps

Table 5.1.2: Description of dominant and common associate species in the seven forest cover types for which silvicultural prescriptions are provided in this guide.

Forest cover type	Dominant species	Common associate species	Number of ecosites[1]	Number of vegetation types[1]	Silvicultural prescriptions provided in
Upland tolerant hardwoods	sugar maple, beech, hemlock, red oak, white ash, red maple, black cherry	• ironwood, basswood, bitternut hickory, white pine, white birch, yellow birch, butternut • in Site Region 6E, black maple • in Site Region 7E, white oak, shagbark hickory, hackberry, and occasionally tulip tree and sassafras	3	19	Section 6.1 
Upland oaks	red oak, white oak, bur oak, and black oak	• white pine, sugar maple, bitternut hickory, red maple, white birch, large-tooth aspen, trembling aspen, red cedar • hickories, black cherry, sassafras, white ash, beech, and chinquapin oak are less common	4	8	Section 6.2 
Lowland hardwoods and swamps	silver maple, swamp (or Freeman) maple (red x silver cross), red maple, green (red) ash, black ash, white elm, yellow birch	• trembling aspen, balsam poplar, basswood, white birch, white cedar, balsam fir, red elm, black maple (7E), red oak (7E), white oak (7E), shagbark hickory (7E), bitternut hickory (7E), butternut, white pine, white ash, sugar maple, large-tooth aspen, bur oak, and willows • in southwestern Ontario, Shumard oak, pin oak, black walnut, tulip tree, sycamore, black gum, hackberry, pumpkin ash.	3 terrestrial, and 11 wetland	13 terrestrial, and 28 wetland	Section 6.3 
Early successional hardwoods	trembling aspen, balsam poplar, cottonwood, large-tooth aspen, white birch	• balsam fir, sugar maple, red maple, red oak, black cherry, white elm, green ash, white ash • in southwestern Ontario, sassafras may be a common associate • stands usually have high shrub and herbaceous cover	3	6	Section 6.4 
Pines	white pine, red pine, and/or jack pine comprise at least 75 % of the canopy cover	• oak species, white cedar, white birch • to a lesser extent, hemlock, balsam fir, red maple, black cherry, basswood, white ash, sugar maple, ironwood	1	2	Section 6.5 
Cedar	either red cedar or white cedar	• on white cedar sites, white spruce or balsam fir, or white birch and poplar • where red cedar dominates, red oak, white oak, black oak, white pine, red pine, ironwood, hickory	3 terrestrial and 2 wetland	7 terrestrial and 2 wetland	Section 6.6 
Hemlock[2]	eastern hemlock	• sugar maple, yellow birch, white pine, balsam fir, white cedar, red maple	2	3	Section 6.7 

[1] As described by Lee *et al.* (1998).
[2] This forest type is relatively uncommon in southern Ontario and typically occurs on mid- to lower, north-facing slopes, seepage areas, bottomlands, and tablelands with high watertable and complex micro-topography.

Recognizing invasive exotic species

During the inventory, landowners and resource managers should note the presence and relative abundance of invasive exotic species. Their early detection is important to inadvertently avoid encouraging their spread through implementation of silvicultural activities that could increase their populations (e.g., increasing sunlight exposure).

It is recommended that forest managers and landowners use basic field guidebooks to learn to recognize the most troublesome exotic species that could be present in or might invade their managed stands, and these are listed in **Table 5.1.3 .** *Newcomb's Wildflower Guide* (Newcomb 1977), *Shrubs of Ontario* (Soper and Heimburger 1990), and *Ontario Weeds* (Alex 1992) are three such guides. **Section 4.2** introduces the topic of invasive exotic species. **Section 8.1** provides autecological information about these species and recommends control treatments.

Table 5.1.3: Most problematic invasive exotic species that occur in forested habitats in southern Ontario

Common Name	Latin Name	ELC Forest Sampling[1] Results	Listed as an Invasive Alien Plant of Ontario [2]	Listed in the Invasive Plants of Canada Project list[3]
Barberry	*Berberis thunbergii* and *B. vulgaris*	10 occurrences; avg. cover=0.2%	Yes	No
Dame's rocket	*Hesperis matronalis*	15 occurrences; avg. cover=5.4%	Yes	Yes
Dog strangling vine	*Cynanchum species*	8 occurrences; avg. cover=17.1%	Yes	Yes
Common buckthorn	*Rhamnus cathartica*	180 occurrences; avg. cover =1.5%	Yes	Yes
Garlic mustard	*Alliaria petiolata*	76 occurrences; avg. cover=12.1%	Yes	Yes
Glossy buckthorn	*Rhamnus frangula*	30 occurrences; avg. cover =1.9%	Yes	Yes
Reed canary grass	*Phalaris arundinacea*	14 occurrences; avg. cover=2.0%	Yes	Doesn't list grass species
Tartarian honeysuckle[4]	*Lonicera tatarica*	20 occurrences; avg. cover=0.9%	Yes	Yes
Norway maple[5]	*Acer platanoides*	None	Yes	Yes

[1] Since most ELC forest sample plots are located in relatively undisturbed, large woodland tracts in southern Ontario, the average cover and number of occurrences of exotic species in these areas are likely lower than in smaller, more disturbed woodlots adjacent to urban/suburban areas.
[2] SER-Ontario. 1996. Plant invaders. Factsheet. 2 pp.
[3] Parks Canada. 1999. Invasive Plants of Canada Project Web Page, http://www.cciw.ca/eman-temp/research/protocols/exotic/append1.htm
[4] Other exotic honeysuckle species i.e., *L. maackii* (Amur honeysuckle), *Lonicera* x *bella* (Bell's honeysuckle), *Lonicera xylosteum* (Dwarf honeysuckle), and *Lonicera japonica* (Japanese honeysuckle) can also be problematic.
[5] More likely to occur in woodland remnants adjacent to urban areas and along 400 series highways.

5.2 ANALYZING STAND STOCKING AND STRUCTURE

by Silvia Strobl


E. Boysen

Managers require an understanding of the current stocking and structure of a stand to determine silvicultural options and predict future improvements that might result from the application of silvicultural prescriptions. These terms are defined and their measurement and application to the management of even-aged and uneven-aged stands are described below.

Definition of stocking

Stocking refers to the density of trees in a stand. Two measures used to estimate stocking are: (1) the total number of trees per hectare and (2) the sum of the cross-sectional areas of all trees measured 1.3 m above the ground (i.e., diameter at breast height or DBH), expressed in terms of basal area per hectare. The higher the basal area of a stand, the greater the proportion of a hectare that is occupied by tree stems. The stand inventory (described in **Appendix C**) will determine both the number of trees and the basal area per hectare for the dominant tree species in the stand.

Both the number of trees and their basal area per hectare are necessary to estimate stand stocking. For example, one hectare of an even-aged stand might contain either 325 trees with a DBH of 30 cm or 1300 trees with a DBH of 15 cm. Both stands would have a basal area of 23 m^2/ha, but the former, with fewer stems of larger-diameter trees, would be more valuable. This information is useful for optimizing both growth and development of trees and returns to the landowner from future timber harvests.

Definition of structure

The spatial distribution of individual trees, from seedlings to sawlogs, is called structure. It represents the distribution of size or age classes among trees in the stand. Ideal stand structure permits full utilization of growing space, thereby maximizing the growth rate that is possible at ideal stocking levels.

Managers make different use of information about stand stocking and structure, collected during an inventory, depending on whether they are developing silvicultural prescriptions for even- or uneven-aged stands, as described in the following.

Even-aged stands

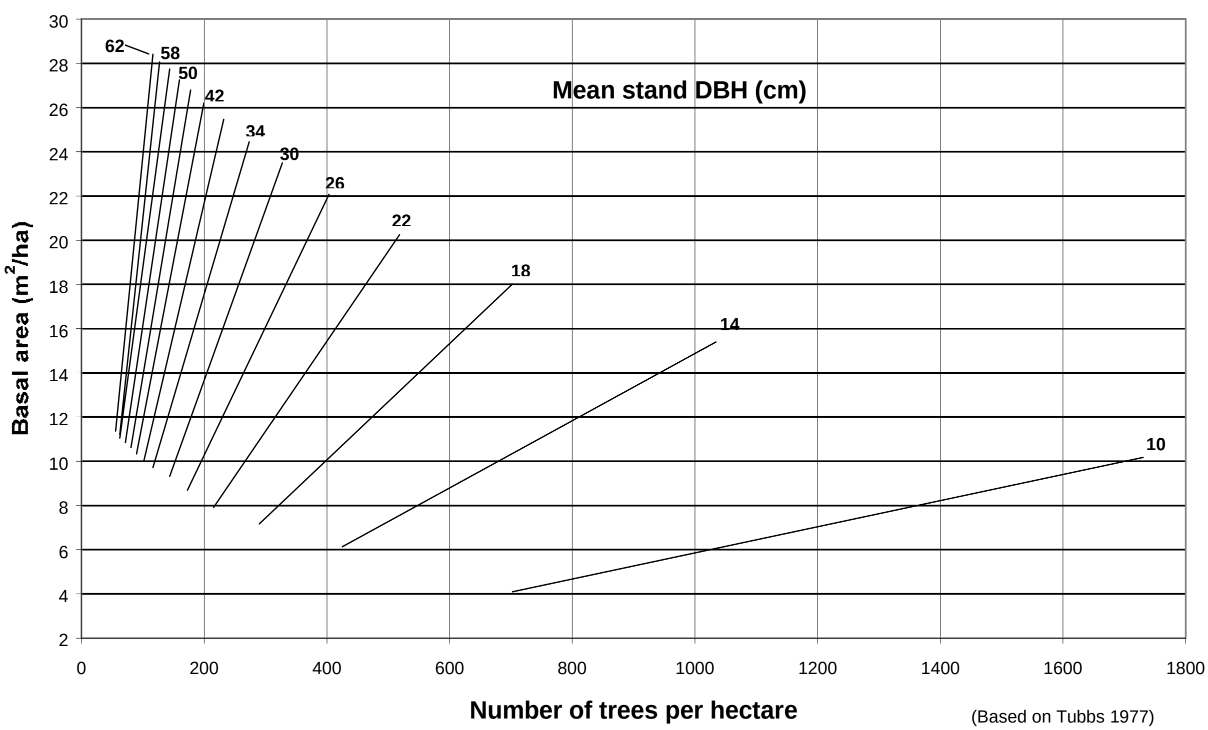
Stocking

In even-aged stands, trees of similar age are grown as an entity, from establishment to harvest, for a specified length of time referred to as a rotation. The curve representing growth over time for trees in even-aged stands is S-shaped, increasing to a maximum, then declining as competition among neighboring trees increases, as horizontally expanding crowns lead to canopy closure and result in individual stems either assuming dominance or gradually dying due to suppression. This stage is referred to as stem-exclusion. Trees fully occupy the site and compete with one another for light, water, nutrients, and space, leading to suppression and death of many other trees. This mortality is induced by competition and results in an upper limit to the average diameter of a given number of trees that can occupy an area.

While the basal area of even-aged stands increases as trees grow in diameter, the rate of diameter growth is controlled by the density of trees. As some trees die or are thinned, surviving trees grow to take up the space. As the trees in the stand get larger, basal area is concentrated on fewer stems. In older stands, increase in basal area results from the growth of fewer trees. **Figure 5.2.1** shows the relationship between the number of trees per hectare and basal area. The numbers in this graph are based on measurements from sugar maple and northern hardwood stands.

Stand stocking determines the timing of thinning in stands being managed by even-aged silvicultural systems (e.g., uniform shelterwood, clearcutting). Optimum stocking is the point at which both growth for individual trees and basal area growth (i.e., volume) for the overall stand are maxi-

Figure 5.2.1: Mean stand diameter expressed as a relationship between number of trees per hectare and basal area.



(Based on Tubbs 1977)

mized. Research foresters have identified optimum stocking levels for different tree species, and these are presented in a format known as stocking guides. An example of a stocking guide is shown in **Figure 5.2.2** to illustrate how they are used. The "A-", "B-" and "C-" lines are stocking thresholds for even-aged stands that are defined as follows:

A-line = over-stocked or too many trees for good basal area growth

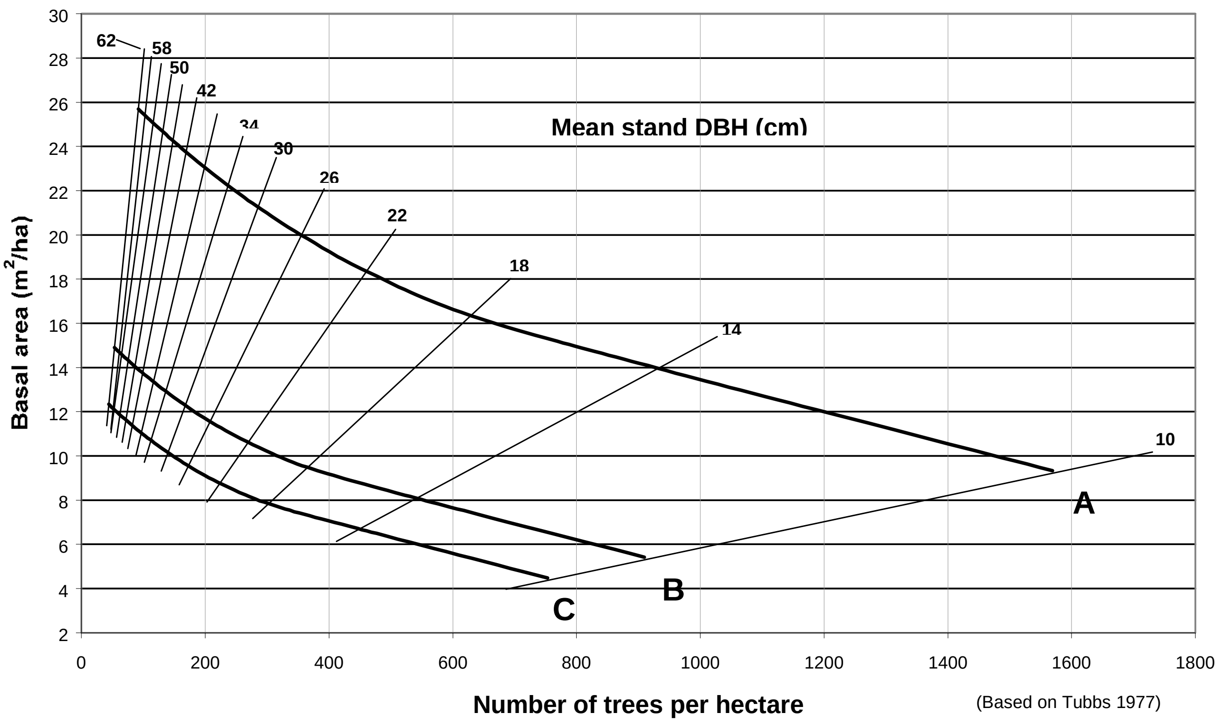
C-line = under-stocked (i.e., diameter growth per tree is good, but there are too few trees to maximize basal area growth rate per hectare)

B-line = optimum stocking to maximize growth rates of individual trees and basal area growth per hectare

Adequately stocked stands fall somewhere between the A- and B- lines. Stands that will be adequately stocked within 10 years, fall somewhere between the B- and C-lines. The position of the A-, B-, and C-lines is based on research and varies by tree species.

To use stocking guides, estimates are required of any two of basal area, numbers of trees per hectare, or mean stand diameter, based on the stand inventory. More detailed information on how to use stocking guides developed for 12 species found in southern Ontario is presented in **Appendix E.**

Figure 5.2.2: A sample stocking guide.



(Based on Tubbs 1977)

Stocking guides are used to determine whether the stand is adequately stocked (i.e., current stocking when plotted is between the A- and B-lines), or overstocked (i.e., current stocking when plotted is above the A-line). If the stand is adequately stocked, premature thinning can be avoided. If the stand is overstocked, stocking guides can be used to determine the number of trees to be thinned by subtracting the number of trees indicated by the intersection of the B-line and average DBH from that shown by the intersection of current stocking and average DBH.

In well-managed stands, thinning may occur two to five times or more during a single rotation. As the stand matures, it becomes more tempting to create more room for smaller trees, by removing some larger trees near them. However, assuming trees of equal quality, these larger trees should be left to grow because they have been proven to be better competitors than nearby smaller trees of the same age and often these smaller trees are suppressed and unable to respond to release. Late in the rotation of the stand, during the final thinning cycles, the thinning prescription may change so that conditions for regeneration of the selected species is improved (e.g., in the shelterwood silviculture system, the spacing of larger crop trees may be increased to provide the necessary light conditions for establishment and development of seedlings).

Use of a stocking guide for thinning prescriptions can help avoid this temptation to remove larger trees before the final rotation. The average stand diameter should be increased through thinnings that focus on removing the smaller, poor quality, and suppressed trees from below, while generally evening out the spacing.

Structure

Even-aged stands tend to be comprised of trees of similar size. When the number of trees is plotted on a graph (along the Y axis) by diameter (along the X axis), the resulting curve of the size class distribution (i.e., structure) is a bell-shape.

Stand structure changes as the stand ages. In one study, young upland hardwood stands in the central United States exhibited moderately skewed (i.e., positive) diameter distributions, but as they matured, these distributions became more symmetrical (Gingrich 1967).

The type of thinning influences stand structure (Anderson and Rice 1993). For example, in thinning from below, the poorest-growing trees are removed since they tend to be suppressed, subdominant trees with smaller diameters. Trees in the upper half of the diameter range are maintained. As a result, the stand structure as represented by a bell curve would change, becoming more skewed to the left.

Figure 5.2.3 illustrates the stand structure of a 60- to 80-year-old even-aged sugar maple stand both before and after thinning. Average stand DBH increased from 13.8 cm to 17.6 cm after thinning from below removed the suppressed, sub-dominant trees with smaller diameters. Thinning from below also increased the average DBH for trees of acceptable growing stock, referred to as AGS (i.e., trees free of defects as discussed in **Section 5.3**) from 13.4 cm to 17.9 cm.

Stand structure has little influence on growth in even-aged stands and is therefore largely ignored when developing thinning prescriptions. In fact, good even-aged thinning actually makes the structure more uniform by maintaining higher quality large- and medium-sized trees while removing most, if not all of the small, suppressed trees as shown in **Figure 5.2.3**.

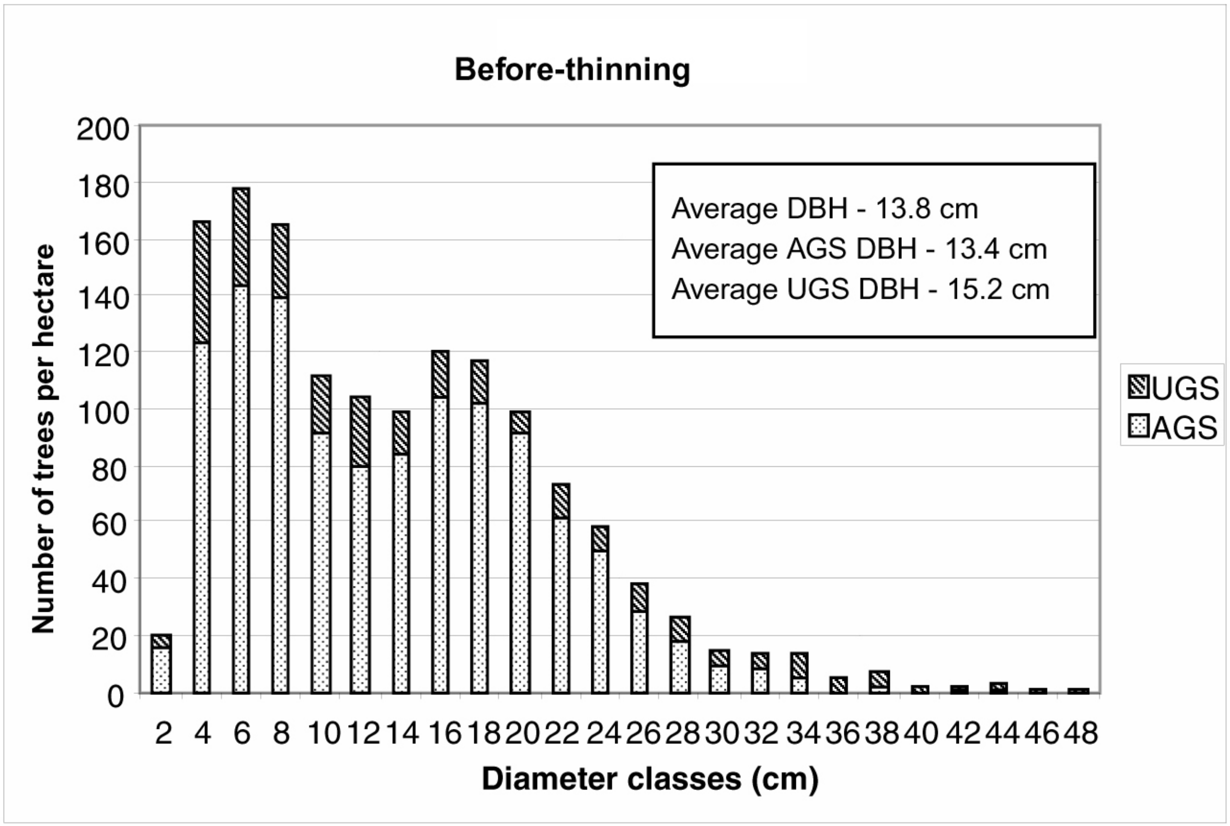
Uneven-aged stands

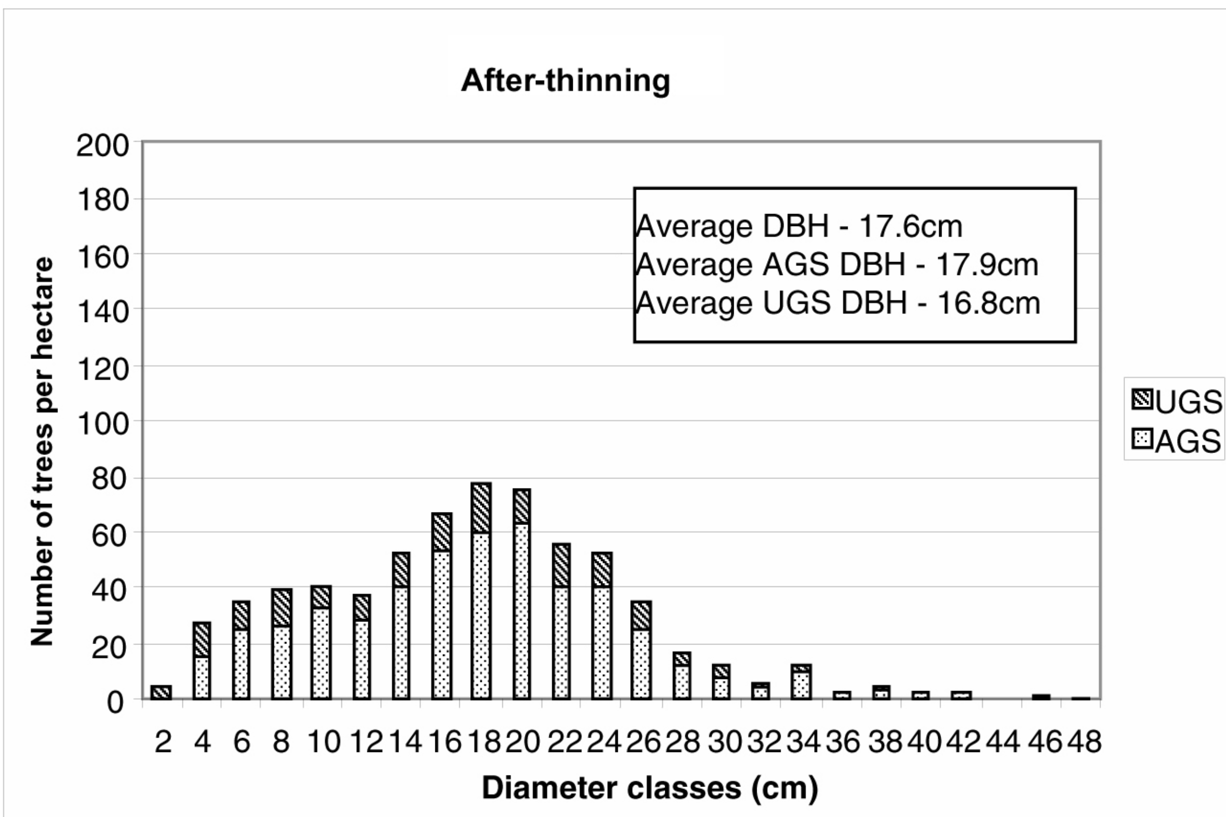
Stocking

In uneven-aged stands, stocking also represents a description of the number of trees or the basal area, by diameter-size class. However, compared to an even-aged stand, there are more diameter-classes spatially intermixed throughout the stand, and at least three age-classes (Smith 1986). Commonly used diameter-class groupings include:

- basal area in trees 1 to 9 cm DBH, representing advanced regeneration of saplings. These trees are not measured during the inventory, but their presence should be noted in the comments field, on a tally sheet such as **Table 5.3.11.**
- basal area in trees 10 to 24 cm DBH, representing polewood growing stock
- basal area in trees greater than 25 cm DBH, representing sawlog components. These trees can be further sub-divided into small (26 to 36 cm DBH), medium (38 to 48 cm DBH), large (50 to 60 cm DBH), and extra-large (> 62 cm DBH) sawlogs.

Figure 5.2.3: Stand structure in a 60 – 80 year-old even-aged tolerant hardwood stand before and after thinning from below.





Stocking guides cannot be applied successfully to uneven-aged stands. In uneven-aged stands both stand structure and overall stand stocking are used to maintain healthy stand growth.

Structure

In uneven-aged stands, an accurate assessment of stand structure is critical because it greatly influences both the development of thinning prescriptions and the sustainability of intermittent harvests. Also, stocking guides cannot be used. Therefore, early research in uneven-aged forest management was concerned with: (1) how much of the basal area of a stand should be removed at intermittent harvest periods and (2) how many trees of each diameter-class should be removed to optimize both growth and form (and, hence, timber quality) of remaining trees to ensure a sustainable harvest of high quality hardwood timber from intermittent harvests (e.g., at 10 to 20 year intervals).

During the late 1930s, in the Upper Peninsula of Michigan, researchers treated a large number of uneven-aged tolerant hardwood stands with a range of seven thinning intensities. They installed almost 120 ha (300 acres) of permanent sample plots. Trees in some plots were measured over a 20-year period, and trees in most plots were measured for at least six years (Eyre and Zillgitt 1953). **Table 5.2.1** briefly summarizes their results by describing the kind of tolerant hardwood forest that grew back 20 years after treatment with each of the three different partial cutting (thinning) treatments.

Table 5.2.1: Summary of uneven-aged stand conditions 20 years after three different intensities of partial cutting (thinning) in the Upper Peninsula, Michigan (Eyre and Zillgitt 1953).

Cutting Type	Description	Stand condition 20 years after cutting
25 cm diameter-limit cut	All trees of at least 25 cm (10”) plus some smaller defective or injured trees were removed.	▪ overstocked with small-diameter stems ▪ rapid diameter growth ▪ many poor quality stems due to excessive limbiness[1] ▪ considerable crown dieback ▪ high mortality due to exposure ▪ stand essentially even-aged ▪ no merchantable harvest (i.e., partial cut) possible
Reserve	No cutting occurred.	▪ overstocked with large-diameter stems ▪ sporadic growth ▪ natural mortality (i.e., death of trees by natural causes) almost offset by growth ▪ few small stems and very little regeneration
Thinning of stems of all diameter sizes	All overmature and defective trees (i.e., those with evidence of decay, poor form) were removed, regardless of size and spacing.	▪ no natural mortality ▪ growth more rapid than with any other thinning type ▪ growth on stems of all diameter sizes ▪ natural regeneration developing well ▪ merchantable harvest (i.e., partial cut) possible

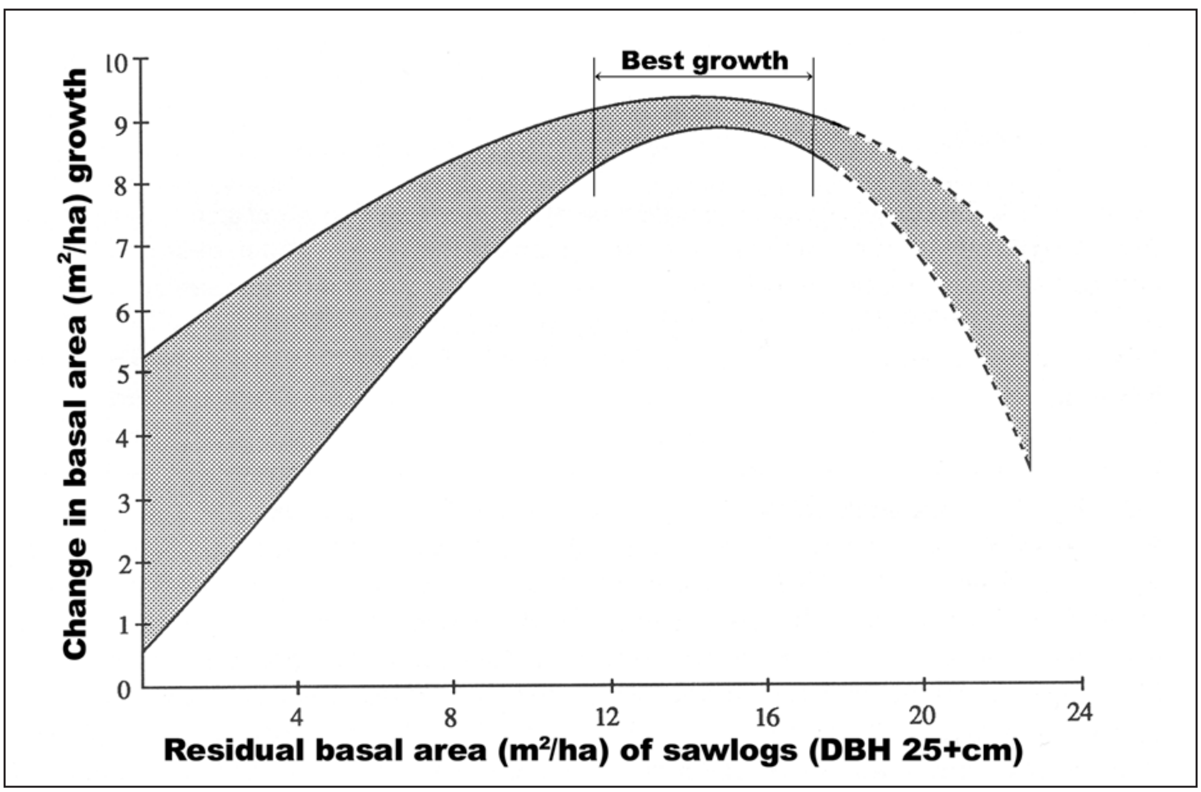
[1] In uneven-aged silviculture, dense shading from the overstory canopy and side competition from the understory will correct forking, keep branches small, prevent epicormic sprouts from developing into branches, and increase clear bole length—all of which result in higher timber quality (Eyre and Zillgitt 1953).

Their research provided one of the earliest indications of the right amount of residual basal area after thinning, and the importance of leaving a balanced distribution of basal area over different diameter-classes. Subsequent research in northern tolerant hardwood forest stands in other regions, including New England (Gilbert and Jensen 1958) and central Ontario at the OMNR Swan Lake Research Reserve (McLean 1987), supported their early results.

Residual basal area — how much to leave

Figure 5.2.4 shows the 20-year growth response for sawlog-sized trees in numerous stands in central Ontario that were subjected to different cutting intensities to produce a variety of residual stocking levels (OMNR 1983). When cuts were too heavy (i.e., leaving a residual basal area of less than 4 m^2/ha), stand growth was limited because the growing space was under-utilized. Although diameter growth was maximized at this residual basal area, stem quality was not. When the cut was too light (i.e., leaving a residual basal area of sawlogs of more than 20 m^2/ha), stand growth was limited by competition and mortality; the larger, mature trees suppressed the smaller trees.

Figure 5.2.4: 20-year change in basal area (m^2), following cutting to various levels of residual basal area (m^2), for trees 25 cm DBH and greater (from OMNR 1983).



Residual basal area—how to distribute it across diameter-classes

Research by Eyre and Zillgitt (1953) also provided some of the earliest guidelines concerning how to achieve balanced stand structure by suggesting the number of trees to leave in each diameter-class, in order to maintain three or more age classes in the stand, with each age class occupying comparable amounts of space. This is accomplished by:

(1) ensuring that some cutting occurs in all diameter-classes, to maintain a specified number of trees per diameter-class in the residual stand, and
(2) removing some financially mature trees from a fixed proportion of the stand area during each cutting cycle.

This approach allows a pre-determined number of trees to move into each progressively larger diameter-class over successive cutting cycles and adequate numbers of desirable trees to develop from regeneration, to fill in the smallest diameter-class (Nyland 1987). It is the large trees of good quality that provide the profit; to produce them the stand must always contain a sufficient number of well-formed, vigorous trees of small and medium sizes, ready to grow into larger diameters.

The number of trees and amount of basal area to leave in each diameter-class are determined by dividing the number of trees in each diameter-class by the number of trees in the next larger diameter-class. The quotient is known as the q-value (Arbogast 1957). The choice of q-value depends on the timber product objectives for the stand. A higher q-value such as 1.7 will produce mostly smaller diameter, pulpwood-sized material while a lower q-value of 1.3 will produce mostly larger diameter sawlogs.

The q-value determines the ratio or balance of trees to leave by diameter-classes. For example, with a q-value of 1.3, the number of trees in the 48 cm diameter-class is 1.3 times those in the 50 cm diameter-class. Note that q-value calculations are affected by the size of diameter-classes used (q-values for 5 cm diameter-classes are higher than for 2 cm diameter-classes). Rather than prescribe specific q-values for southern Ontario, this guide provides three sets of ideal basal area by diameter-class recommendations to accommodate different landowner objectives (**Tables 6.1.3 to 6.1.7**).

In tolerant hardwood stands, it often takes a few cutting cycles to achieve the ideal diameter distribution. This process can be slower in stands that were previously high-graded or subjected to diameter-limit cutting because they frequently lack large trees and tend to be overstocked with poor quality trees in the smaller diameter-classes. The early improvement cuts usually focus on removing poor quality trees. In many stands, more low quality trees are initially retained because higher stocking than is normally desirable in the largest remaining size class (e.g., medium sawlogs) is necessary to accommodate the understocked nature of the large sawlog diameter-class.

The length of cutting cycle is flexible and is determined by a number of factors including: (1) the growth rate of the stand in the particular climate and site conditions (i.e., time required to allow the stand to accrue 6 – 10 m^2/ha so that its basal area can then be reduced again by up to one-third to 21 m^2/ha); and (2) economic considerations (e.g., how much total timber volume is required to interest a buyer in picking it up).

Consideration of stand structure is critical to uneven-aged forest management. Sustainable timber production can occur only when the diameter-class distribution or stand structure is balanced (i.e., all diameter-classes are represented in the stand) because continual harvests depend on enhanced growth of released smaller diameter-class trees that will eventually replace harvested trees. Therefore, the recruitment of sufficient numbers of seedling and sap-ling trees (less than 10 cm DBH) is especially important (Anderson and Rice 1993). At the same time, the improvement and thinning of the polewood and larger classes ensure growth is allocated to the most potentially valuable trees.

Residual stocking level or basal area will influence the following factors:

- length of cutting cycle. The shorter the time between periodic harvests, the higher the residual basal area needs to be to ensure that there will be sufficient growing stock on which each successive harvest depends, thereby maintaining the sustainability of the stand.
- maximum DBH. The larger the average size of tree desired at harvest for production of specific wood products such as saw- or veneer logs, the higher the residual basal area needs to be, given that length of cutting cycle and expected growth rate are the same.
- expected growth rates. On more productive sites with deeper, more fertile soils and/or more growing degree days, cutting cycles can be shortened, trees of greater average size can be grown, and the residual basal area that maximizes growth can be higher.

For example, farther north in Site Region 5E (Central Ontario), a residual basal area of 14 m2/ha is recommended for trees greater than 24 cm DBH (OMNR 1983). Still farther north, in Site Region 4E (Algoma and the northshore of Lake Superior), residual basal areas of 12 m2/ha for trees greater than 24 cm are more appropriate (Rice et al. 1998). For southern Ontario (Site Regions 6E and 7E), the OMNR recommends using the 15 to 16 m2/ha stand structure targets for timber production developed in the Great Lake States (Arbogast 1975) as shown in **Table 5.2.2**. A more detailed version of **Table 5.2.2** by two centimeter diameter-classes, is provided in **Table 6.1.4**.

Table 5.2.2: A recommended ideal residual basal area distribution for southern Ontario tolerant hardwood forests (adapted from OMNR 1998a).

Size Class	Diameter Class Range (cm DBH)	Basal Area (m2/ha)	Trees (#/ha)
Polewood	10 to 24	4	184
Small Sawlogs	26 to 36	5	70
Medium Sawlogs	38 to 48	6	40
Large Sawlogs	50 plus	5	22
Total		**20**	**316**

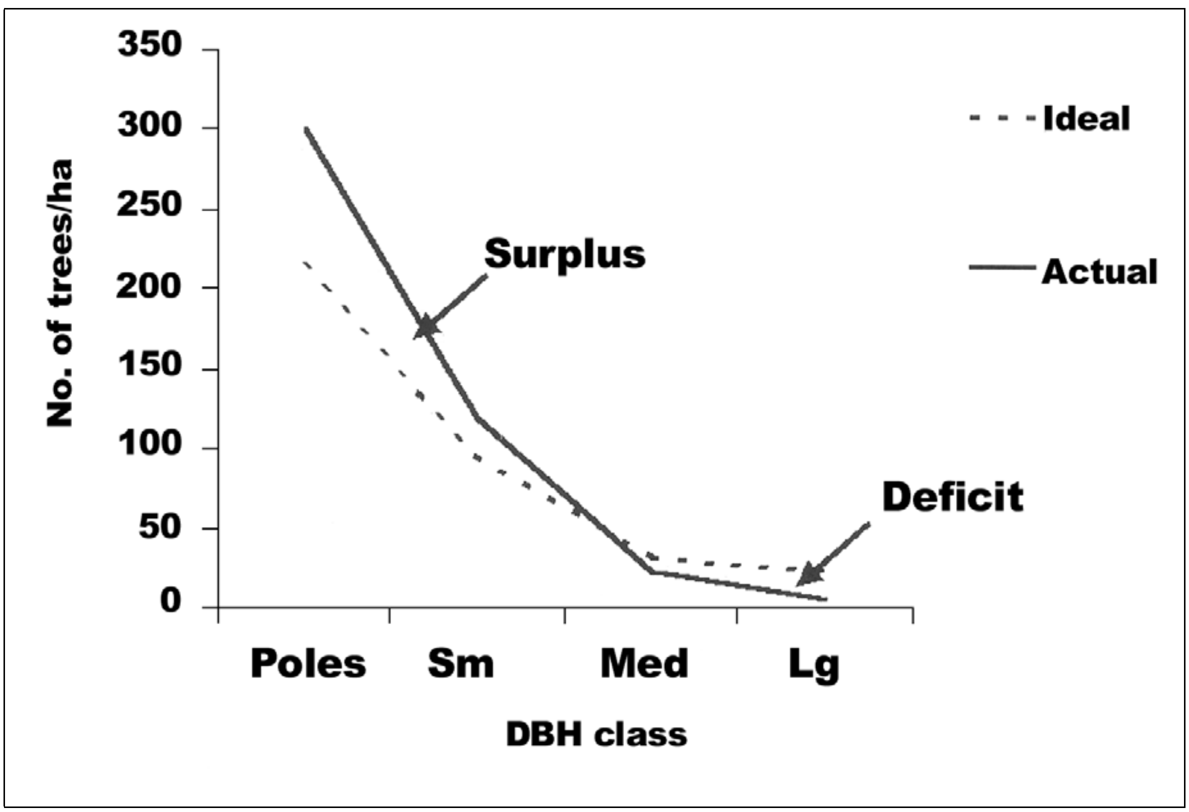
[1]The suggested residual basal area of 16 m2/ha for trees > 25 cm DBH (i.e., the combined BA of small, medium and large sawlogs with basal areas of 5, 6, and 5 m2/ha, respectively) corresponds well with the recommendation of Eyre and Zillgitt (1953) that 14 m2/ha residual basal area be in trees of this size. The southern Ontario recommendations also specify that 4 m2/ha of polewood and I m2/ha of saplings be grown in addition to this sawlog component, for a total BA of 21 m2/ha.

The distribution of basal area in a stand being considered for uneven-aged management may vary among the diameter-classes, depending on site and stand history. For example, undisturbed stands usually have much of their basal area in the largest trees and have developed a two-storied appearance. High-graded stands may have little basal area in large trees except for in those of poor quality because of past intense harvesting of merchantable trees (OMNR 1998*a*).

Data obtained from the stand inventory can be used to compile a stand stocking table representing the current stand structure. Then it can be compared to the ideal or recommended stand structure in **Table 5.2.2** (or one of **Tables 6.1.4** to **6.1.7**) to determine the number of trees that should be removed, by diameter-class.

In **Figure 5.2.5**, very few large-diameter trees would be removed since the actual number of such trees is less than ideal. Therefore, for this woodlot, the target basal area to be left after partial harvesting may actually contain more small and medium-sized sawlogs to compensate for the less than ideal basal area in large sawlogs. The target basal area forms the stand prescription provided to the tree-marker(s) for implementation (**Section 8.2**).

Figure 5.2.5: Comparison of recommended or ideal stand structure to actual diameter distribution (as determined from stand inventory in a typical high-graded tolerant hardwood stand).



Which trees to cut; which trees to leave

It is important to retain the right trees (by diameter-class) by considering individual tree quality. Once the number of trees per hectare to be removed by diameter-class is known, consideration of tree quality becomes important. To maximize timber production, forest managers prefer to leave as many higher quality trees in the diameter-classes that have the greatest growth potential so that they can accrue wood volume to be harvested in subsequent cutting cycles.

In most stands where uneven-aged management systems will be used, at least two cutting cycles will be necessary to obtain the recommended structure and stocking level that then continues to produce a harvest of high quality trees at each subsequent cutting cycle. During early cutting cycles, retention of poor quality trees may be necessary to avoid reducing stand basal area by more than one-third, thereby minimizing the risk of stimulating epicormic branches that result in decreased timber quality of residual trees. The proportion of crop trees will increase with careful management.

One of the most important research findings resulting from the OMNR forestry research studies at Swan Lake Research Reserve in Algonquin Park concerned the effects of various decay fungi and several abiotic factors on stain and defect in sugar maple (Anderson 1973). This research showed that by removing overmature and defective trees (i.e., trees likely to die from natural causes, such as decay fungi, before the next cutting in 20 years), growth of remaining or residual stems could be maximized and the timber quality of the stand could be improved. For example, one study at Swan Lake Research Reserve found that the percentage of trees with a quality expected to improve over the next cutting cycle increased from 13 to 35 % over the 20-year period from 1967 (first cut) to 1987 (second cut).

5.3 ANALYZING QUALITY OF TREES IN THE STAND

adapted from Anderson and Rice 1993

Determining silvicultural options and future improvements that might result from the application of silvicultural prescriptions requires an understanding of the current stand quality. High value wood products (e.g., saw- and veneer-quality logs) can only be derived from high quality trees. Therefore any silvicultural thinning prescription must not only recognize the characteristics of quality in standing forest trees, but also understand how these can be maintained or improved over time.

Tree classification systems are used to evaluate potential tree vigor, risk, and current tree quality, in order to determine which trees to retain (i.e., the crop trees) when applying both even- and uneven-aged silvicultural system prescriptions (OMNR 1998*a*). Readers are advised to see *The Ontario Tree Marking Guide* (OMNR 2000) for a more complete discussion about how to assess tree vigor, risk, and quality potential.

Potential tree vigor

Potential tree vigor is defined as the relative capacity of a tree to increase in size (OMNR 1990). An understanding of crown position, size, architecture, and quality; bark character; and degree of competition is required to properly assess tree vigor. These features are used to select crop trees in a stand with the best potential for maximum growth and high financial returns from future harvests. Potential vigor of trees to be retained is predicted by considering their crown and bark characteristics, and the changes to these anticipated by removal of neighboring tree competition.

Crown position

Growth rates of individual trees vary within a forest stand. Some trees encroach on the growing space of others, increasing the size of the former at the expense of the latter. This results in a process of crown differentiation. In even-aged stands consisting of a single species, crowns usually develop in a single layer, but mixed intolerant species may develop several strata. Uneven-aged stands of shade-tolerant species often have a continuous vertical distribution of foliage (canopy) because suppressed trees have reduced height growth but do not die.

In uneven-aged tolerant hardwood stands, natural disturbances, as well as harvesting and other silvicultural activities, often expose lower canopy crown classes to overhead sunlight. This allows these trees to accelerate their height growth for a brief period of time and may promote gradual entry of their crowns into the upper canopy stratum (Anderson and Rice 1993).

Classifying trees by their crown position in relation to the forest canopy provides an indication of the amount of direct sunlight received by them, an important factor that influences photosynthetic rates and subsequent diameter and height growth of the trees. **Table 5.3.1** distinguishes four crown positions.

Table 5.3.1: Crown position classification (adapted from Trimble 1969 and OMNR 1998*a*).

	**Crown position**	**Amount of sunlight received**
Dominant (D)	Tree taller than its immediate neighbors.	Receives full light from above and considerable light from the sides.
Codominant (C)	Tree with crown formed at the general level of the crown canopy.	Receives full light from above but comparatively little from the sides.
Intermediate (I)	Tree shorter than dominants or codominants but with crown extending into the canopy formed by them.	Receives some direct light from above but none from the sides.
Overtopped or suppressed (S)	Tree with crown entirely below the general level of the crown canopy.	Receives no direct light.

Crown size

Crown size, as expressed in terms of crown length and width, determines the leaf surface area available for photosynthesis, and hence is an indirect measure of potential tree growth. Long crowns produce wood volume inefficiently since they shorten the merchantable bole length, while wide crowns seldom respond to release. Short, narrow crowns produce timber of desirable size very slowly, even after release (OMNR 1998*a*). Often the most productive stands are characterized by an efficient vertical distribution of foliage in the canopy (Anderson and Rice 1993).

Crown diameter (in meters) is usually expressed as a percentage of crown length or in meters per centimeter of DBH. Taken together, crown length and diameter are used to determine optimum crown sizes that maximize growth potential. Measurements in central Ontario sugar maple polewood stands (Anderson 1985) have substantiated a recommendation by Smalley (1975) that for most tolerant hardwood species, a tree with a crown diameter of 0.20 to 0.25 meters per centimeter of DBH will grow at close to maximum rate while maintaining height and self-pruning ability.

Crown architecture

Crown architecture refers to the arrangement of foliage within the crown. Both crown position and shade tolerance influence crown architecture. In full sunlight or relatively high light intensity conditions, the ideal crown of a shade-tolerant species should have leaves distributed throughout the total branch volume (i.e., interior leaves receive enough light to balance their metabolic needs) resulting in a multi-layered crown. In low light conditions, however, an ideal crown should intercept all available light at the highest possible intensity. In this case the ideal crown is a narrow layer of leaves in a shell around the crown surface, referred to as a mono-layered crown. Shade-tolerant trees in dominant or codominant crown positions (i.e., those exposed to high light intensities) with multi-layered crowns will exhibit better tree vigor potential than those with mono-layered crowns.

Crown quality

Regardless of position, size and architecture, the crown must be healthy to maximize photosynthesis and tree growth. High quality crowns are symmetrical, showing even development on all sides with little evidence of excessive whipping or crowding damage. Vigorous trees usually show fine branching, with the numerous branchlets and twigs contributing to a dense crown with a large leaf area. In their juvenile years, vigorous trees tend to demonstrate strong apical dominance (i.e., no forking).

Less vigorous trees exhibit coarse branching (except some species like white ash that are naturally coarsely branched), with some dead limbs and a discontinuous canopy. Also they may have undersized or chlorotic (yellowing) leaves, low leaf density, and a flat-topped profile that is indicative of poor apical dominance (Anderson and Rice 1993).

Crown breakage resulting from wind, snow, or harvest damage may reduce vigor potential, especially in sugar maple, pine, and white ash trees with forked stems.

Forked stems in conifer species are undesirable except as potential raptor nest sites. However, narrow forks in the upper crown are generally acceptable. In conifers, decline that causes loss of needles and exposes crown branches to view, indicates trees with low vigor.

Bark character

Tree vigor of some species can be determined by examining the firmness of the bark and the nature of its fissures and ridges. The bark must accommodate the rapidly growing stem diameters and some bark characteristics indicative of high and low tree vigor potential are listed in **Table 5.3.2**. *The Ontario Tree Marking Guide* (OMNR 2000) provides numerous photos that illustrate low and high vigor bark characteristics for several tree species.

Table 5.3.2: Bark characteristics indicative of high and low tree vigor potential (based on Anderson and Rice 1993).

	Indicators of high vigor	**Indicators of low vigor**
Rough-barked species (sugar maple and red oak; to a lesser extent, white ash and black cherry)	Furrows are: • prominently vertical in pattern • relatively narrow • V-or U-shaped in profile • less than 1.3 cm deep • light in color at base • less broad than plates or ridges Ridges are: • firm	Furrows are: • often marked with cross-breaks in their vertical pattern • much broader than plates or ridges Ridges are: • soft and corky
Smooth-barked species (yellow birch, beech, but not hemlock)	• smooth, thin and if peeling, then very thin strips (more likely for younger and therefore faster-growing trees for their size)	• rough, with large flaky plates

Degree of competition

The stocking density of some of their competitors affects the current growth rate of potential crop trees. Removal of companion trees will provide an opportunity for accelerating growth and improving quality of residual trees, depending on their response to release. Species that respond favorably to competition and release from competition will have higher tree vigor potential (**Appendix B**).

Marking to improve vigor

Individual tree vigor must be considered with respect to the overall management objectives for stand density, structure, and species composition as discussed earlier in this section. Managers should decide which trees to remove or retain by comparing the structure and stocking of the stand under management to desired stand structure and stocking targets. Then tree marking is done to attain stand objectives by optimizing, rather than maximizing, the performance of individual trees.

Stand density affects stand growth by influencing the distribution of growing space available to individual trees. In young, even-aged stands comprised of only a few species, DBH is the best practical indicator of growth potential. In older, more diversified even-aged stands, both DBH and crown position (**Table 5.3.1**) provide a better index (Anderson and Rice 1993). For example, mature red and white pine stands are managed to optimize growth on residual stems in the medium to large sawlog classes due to their large crowns, superior seed production, and volume growth potential.

In uneven-aged stands at an early stage of management, DBH of trees reveals little about future growth potential because age tends to vary widely (sometimes by more than 100 years) within a narrow range of DBH (Gibbs 1963; Blum 1961, *in* Anderson and Rice 1993). In selecting trees to retain, tree-markers should assess the current crown position and the probability of its improvement if competing trees were removed. Bark characteristics will indicate those trees with higher potential vigor.

Potential tree risk

At the same time that trees are assessed for vigor characteristics, tree-markers should also assess defects that can lead to the decline of a tree. To be valuable for timber production, residual trees must survive and grow at least until the next cutting cycle, normally occurring within eight to 20 years. High risk trees may either die or deteriorate significantly in quality due to rot development, structural defects, damage, and/or other factors during that period. Therefore they are usually removed from the stand. However, as mentioned earlier, in some degraded stands, trees of lower quality may have to be retained to avoid reducing the stand basal area by more than one-third. Conversely, vigorous and normally valuable trees may be considered to be high risk, low value trees because of crown damage or excessive lean (OMNR 1998*a*). Although high risk trees may have little value for timber production, some of them should always be retained for wildlife habitat (e.g., current or potential cavity trees and snags that present no risk to forest operators or other human users of the forest).

Table 5.3.3 lists some of the defects that cause tree decline or conditions that contribute to increased tree risk. Further descriptions and color photographs to assist with their identification are provided in *The Ontario Tree Marking Guide* (OMNR 2000).

Crown dieback or decline may also indicate serious potential risk. **Table 5.3.4** lists several stress-induced causes of crown dieback or decline that commonly occur in southern Ontario. Trees in all vigor classes can die or deteriorate when they are stressed by defoliation. Abundance of food reserves (i.e., root starch) is an index of vigor; high starch content indicates good tree vigor and consequently low potential risk (Anderson and Rice 1993).

Stresses such as defoliation, drought, and pollution reduce starch content. After severe defoliation, starch levels in sugar maple were significantly reduced only in those trees that regained their foliage in the same year. They probably depleted their starch reserves to accomplish this. After a single defoliation, trees depleted of starch require one full season to recover (Anderson and Rice 1993).

In sugar maple roots, chemical changes induced by defoliation stimulate the growth of *Armillaria*, a fungus causing the decline and death of defoliated oak species. In defoliated sugar maples, slow growth rate and increased bark necrosis resulted in a retarded rate of wound closure and was directly correlated with starch content (Anderson and Rice 1993).

Tables 5.3.5 to **5.3.8** in the following section on current tree quality list the common causes of tree defects, their symptoms, and recommended action to help tree-markers choose the right trees to retain.

Table 5.3.3: Some defects causing tree decline, effects on tree risk potential, and recommended actions.

Defects	Effects on tree risk potential	Recommended action
Armillaria root rot	• infects the roots, causing progressive root rot that often develops into a hollow butt condition • eventually infected trees become vulnerable to windthrow or breakage • also known as shoestring root rot because of the appearance of the mycelia beneath the bark • mycelia infect other roots in the soil and are an important source of stump-to-sprout infection in oak	• considered a major defect; infected trees should be removed
Beech bark disease	• infection of trees follows primary feeding injury by beech scale aphids • disease is usually fatal within 10 years of infection	• infected trees should be removed
Cobra canker and target canker	• kill maple trees by progressively girdling the stem; target canker also affects yellow birch, white ash, American beech, black cherry, and red oak • infected trees often suffer wind breakage before girdling is complete, particularly after harvesting has increased their exposure	• although target canker is somewhat less virulent than cobra canker, both present a high risk and infected trees should be removed
Pine engraver beetles	• male beetles cut holes through the bark to the wood where beetles construct egg-laying galleries • kill the vascular system of the tree	• trees damaged by this beetle should be removed
Root injury during harvesting	• can predispose sugar maple to infection by root rot fungi and sapstreak • extensive root damage weakens tree, resulting in possible decline and windthrow	• root wound with > 25 % of roots exposed within the drip line of the tree crown is considered a moderate defect • to prevent injury, follow careful harvesting practices outlined in **Section 8.3**
Severely leaning trees	• susceptible to windthrow, especially if some of their roots are above-ground or rotten • exposed trees (e.g., those on a ridge or edge of a stand) and shallow-rooted trees (resulting from a high water table and shallow soils) are also prone to windthrow	• considered a moderate defect if lean is > 10 degrees (i.e., can be retained if required to meet residual BA target) • remove tree if quality is expected to continue to decline or if it is competing with trees with greater potential vigor
Snow-loading pressure (on forked trees)	• can split trees with forks, exposing them to infection by rot fungi • decay further weakens these trees and makes them more susceptible to breakage	• carefully weigh removal of such trees against their wildlife habitat benefits since forked trees often provide valuable stick nest sites for raptors
Yellow-bellied sapsucker	• will drill holes and feed on all species but are especially attracted to hemlock and yellow birch • heavy feeding (i.e., 50 or more holes in a band or patch) can lower wood quality, reduce growth, and may cause mortality	• trees with heavy feeding damage should be removed

Table 5.3.4: Some stress-induced causes of crown dieback or decline, effects on tree risk potential, and prognosis for recovery.

Stress	Effects on tree risk potential	Prognosis for recovery
Decline[1]	From 1986 to 1998, surveys of the health of 110 forest observation plots in southern and central Ontario found: • The average level of decline for 76 % of plots was low or very low. • Only 3 % of plots showed severe decline (McLaughlin *et al.* 1999).	• Short-term stresses (e.g., feeding by leaf defoliating insects, drought) may result in crown dieback, but annual monitoring for 12 years in Ontario has shown that stands usually recover from such stresses after a few years.
High pollutant levels	• may contribute to poor growth on acid-sensitive soils (i.e., shallow, sandy soils, more common on the Canadian Shield)	• Pollutant deposition in southern Ontario and Quebec is generally higher than in other forests in Canada (Miller *et al.*1990 *in* Canadian Forest Service 1999), but the clay soils of southwestern Ontario are better able to neutralize acidic fallout.
Insect defoliators (e.g., forest tent caterpillar, gypsy moth)	For trees defoliated by forest tent caterpillar: Three or more successive years result in mortality and/or growth loss (Gross 1985).	For trees defoliated by forest tent caterpillar: • Dominant and codominant maples with branch mortality of less than 40 % in 1978 generally recovered, exhibiting good vigor and crown shape by 1990 (Gross 1991).
Windstorm, ice storm injury (e.g., broken tops and branches, bent stems)	• can increase the risk of a pest outbreak by weakening tree defenses • uprooted trees are susceptible to stains, decays, and invasion by insects • pines are more susceptible to subsequent pest outbreaks than hardwoods • pines with major wounds to the lower bole are susceptible to attack by bark beetles • dead and dying trees in a stand are susceptible to attack by wood borers. Although this can be detrimental to the stand, it may also be beneficial, as it can quicken the decomposition of waste material. Local stand and site conditions will dictate which management options are appropriate. • trees that are turning yellow, or those with pitch tubes on the bark or red boring dust around the base, are probably affected by insects and/or diseases (Meating *et al.* 1999)	• Stands should be monitored periodically for subsequent pest activity and damage. • Salvage operations should be delayed for a year or two to assess the true impact of crown dieback or damage (Meating *et al.* 1999).

[1]The main visible signs of decline in hardwood trees are pale green or yellowed leaves, abnormally small leaves, and the dying back of the fine twig structure, followed by the death of the main branches.

Current tree quality

The quality of trees in terms of timber value is based on their relative freedom from value-limiting defects. Such defects are considered to be either (1) scalable defects (measured using log-scaling methods) such as rot or shake that reduce the sound, usable volume or durability or (2) grade defects such as knots or stain that reduce strength or utility.

Even though quality defects are difficult to discern without cutting down the tree, numerous methods to estimate defect from external features have been developed. External indicators of tree defects are divided into (1) biotic, including defects attributable to the action of organisms and (2) abiotic, including defects associated with injuries arising from various non-biological origins. Common defects of hardwood trees are listed and described in **Tables 5.3.5, 5.3.6** and **5.3.7.** Common defects of conifer trees are listed and described in **Table 5.3.8**.

Color photographs and descriptions to help identify these defects, are provided in *The Ontario Tree Marking Guide* (OMNR 2000). To help tree-markers assess the ability of individual trees to increase in volume, form, quality, and value after release, defects are classified as described in the following.

Tree defect classification

Tree defect classification systems group defect indicators into categories of major, moderate, and minor importance to tree quality. **Tables 5.3.5** to **5.3.8** present defects by major, moderate (considered significant in conifers), and minor classes, respectively, according to their potential to affect tree quality potential. Trees with major defects are expected to degrade rapidly (i.e., within the eight- to 20-year cutting cycle) and are referred to as Unacceptable Growing Stock (UGS). Moderate defects are expected to degrade slowly, and are referred to as Acceptable Growing Stock (AGS), although some may exhibit more severe symptoms that should be considered UGS. Trees with minor defects are expected to maintain their quality over the cutting cycle. Trees with major defects should be removed. Trees with (most) moderate and minor defects can be retained, especially if required to meet residual BA targets.

Table 5.3.5: Major abiotic (A) and biotic (B) defects that reduce quality potential in hardwoods and recommended action. Trees with these defects will degrade rapidly (UGS).

Defect agent	How to identify	Effects on tree quality potential	Recommended action
Spine-tooth fungus (B)	• large, soft fruiting body (conk) that occurs on trunk as shelf-like clusters; conk has spines or teeth on undersurface • annual conks are killed by frost, but a white blotch mark on the stem indicates the location of previous conks • mainly infects hard maple	• indicates 4 – 5 m vertical decay column above and below conk • hedgehog fungus causes a similar rot in other hardwoods	• remove infected tree
Punk knot (B)	• black, cinder-like plugs that form on trunk at old branch stubs; often become swollen by callus growth • fungus does not fruit on living trees • can produce linear, sunken cankers that retain the bark through which black stroma may eventually erupt to form a "Black Seam" • infects hard maple and beech	• in hard maple, indicates a 1.5 - 2.1 m vertical decay column above and below conk • in beech, indicates a 1.5 - 1.8 m vertical decay column above and below conk	• trees with several conks should be removed
False tinder fungus (B)	• hoof-shaped perennial conk that occurs on trunk • conk is gray-black on upper surface with whitish outer rim, and rust-colored on lower surface • can be differentiated from tinder fungus by the conk's rounded lower surface • infects hard maple, American beech, and occasionally white ash • a related variety (var. *laevigatus*) occurs exclusively on yellow birch, and the conk is more flattened against the trunk	• causes major heart rot: a single conk usually indicates a decay column of 5 m, often representing 50 % cull • trees with this disease attract woodpeckers because they are easily excavated	• remove infected tree
Clinker fungus (B)	• large plugs that are initially yellow but become black, rough, hard and cinder-like, and may form a canker • found almost exclusively on yellow birch	• indicates a 1.5 - 1.8 m vertical decay column above and below conk	• more than a single protruding, black, sterile conk indicates a cull tree that should be removed
Artist's conk (B)	• conspicuous shelf-like conks look like an elephant ear and occur mainly on the lower bole • upper surface is gray or brown and underside is white with visible pores • can infect all hardwood species	• a scavenger rot (i.e. found on dying trees) that causes extensive white, mottled sap and heart rot	• remove infected tree
Shoestring root-rot (B)	• honey-colored mushrooms appear in late summer in clusters at the base of infected trees but are short lived • may also be recognized by the presence of tough, dark brown, stringy "rhizomorphs" under the bark and on roots • advanced decay may produce an exaggerated flare or barelling • mainly infects hard maple, but also American beech, yellow birch, black cherry, red oak, red pine, and hemlock	• appears to be virulent only on trees that have been weakened by stress and is often cited as a contributing factor in tree decline • causes butt and root decay • flare or barelling indicates a hollow butt with rot extending above the swelling by as much as 2 – 3 m	• remove infected tree • infected trees are prone to windthrow
Coal fungus (B)	• thin, crust-like, with black carbon-like color • fruiting bodies are inconspicuous • occurs on butt of hard maple and beech	• causes primary rot in living trees • vertical decay column extends 1.0 – 2.7 m above conk	• a serious butt rot • a major source of infection from stumps to sprout stems • remove infected tree

Table 5.3.5: *continued*

Defect agent	How to identify	Effects on tree quality potential	Recommended action
Yellow cap fungus (B)	• yellow cap mushrooms that form annually in late summer • yellow, sticky, somewhat scaly stems and caps that occur in clusters at wounds or seams • advanced decay indicated by a hollow stem • infects hard maple and yellow birch	• presence of mushrooms indicates significant rot • produces a yellow-brown stringy trunk and a hollow stem	• remove infected trees
Butt flare, barrelling (B)	• a portion of stem with an unusually large diameter • unusual change in taper of lower bole • found on hard maple and yellow birch	• may be caused by buttress growth associated with advanced coal fungus, punk knot or *Armillaria* decay	• remove infected tree
Black bark (B)	• crack in bark with black, wet ooze • fungi grow on sap discharges from fluxing seams • internal gas pressure, associated with bacterial wetwood and decay force sap through the crack onto the bark • mainly infects hard maple	• is indicative of internal wetwood infections that are often associated with advanced decay and extensive cull	• remove infected tree
Cobra canker (B) and target canker (B)	cobra canker: • on trunk; cobra-like swelling around canker • can infect hard maple target canker: • on trunk; canker is usually free of bark with concentric callus ridges; black fruiting bodies • can infect all hardwoods	• kill trees by progressively girdling the stem • infected trees often suffer wind breakage before girdling is complete, particularly after harvesting has increased exposure • cobra canker indicates vertical decay column about 1.5 X canker length	• although target canker is somewhat less virulent than cobra canker, both present a high risk and should be removed
Darkface scar (A), for example, from mechanical injury during harvesting	• gray-black, moist, somewhat spongy surface usually associated with a trunk wound • all tree species are susceptible	• the larger the wound, the greater the associated decay column • >968 square cm (i.e., approximately 32 x 32 cm) indicates major decay • scars on yellow birch only need to be 60 % of the above size to indicate major decay	• trees with scars >968 square cm should be removed • if scar is <968 square cm, tree is considered UGS only if scar touches the ground • whiteface scars are considered a minor defect
Tinder fungus (B)	• hoof-shaped perennial conk that occurs on trunk • conk is gray-black on upper surface with whitish outer rim, and rust-colored on lower surface • can be differentiated from false tinder fungus by the conk's flat lower surface • can infect all hardwoods, mainly found on declining or dying trees, primarily yellow birch	• a scavenger rot that mainly decays sapwood and heartwood of dead timber	• remove infected tree
Crown 50% defoliated (B) for example, from insect feeding	• half the crown or more is leafless during the growing season	• this amount of defoliation weakens trees and often increases susceptibility to infection by major defect-causing fungi (listed above)	• remove afflicted tree
Seam: infolded, open (A and B)	• usually an open seam on trunk with evidence of decay • caused by very cold weather in trees that have an internal core of moist mineral stain • outside living tissue near the bark shrinks in cold weather while inner moist core freezes and expands, causing outer bark and wood to split • mainly found on maple	• indicates deep cavities in the stem and cull trees unless confined to a very local position • creates an infection zone for entry by other major defect causing fungi (listed above) • seams frequently re-open	• remove afflicted tree
Sulphur fungus (B)	• brightly colored, profuse fruit bodies • occasionally occurs on hard maple, white ash, black cherry, and red oak	• causes brown cubical rot	• remove infected tree

[1] Two significant defects on the same tree are considered a major defect.

Table 5.3.6: Moderate[1] abiotic (A) and biotic (B) defects that reduce quality potential in hardwoods and recommended action. Trees with these defects will degrade slowly AGS (but may be considered UGS if defect is severe).

Defect agent	How to identify	Effects on tree quality potential	Recommended action
Mossy-top fungus (B)	• white, soft, spongy perennial conk that appears water-soaked • usually has green moss or algae on upper surface • lower surface is white and contains spores • frequently occurs on lower butt in clustered layers • mainly found in hard maple	• causes a lower-trunk decay column of limited extent • indicates vertical decay column usually 1 to 1.5 m above and below conk • often associated with other defects such as open seams, sunscald, fire scars	• consider removing tree, especially if it is not required to meet residual stocking target
Spiral seam (A)	• seam spirals around the stem, often going around 360 ^{o} • can affect all hardwood species, but particularly beech	• indicates 100 % cull if seam is infolded or open • if seam is tight, indicates a vigorous tree and will represent significant grade defect for certain products (such as veneer and lumber), due to mechanical limitations on production	• considered AGS if seam does not completely circle around the tree's circumference, otherwise considered UGS (i.e., tree should be removed)
Insect borer wounds caused by sugar maple (B)	• initial wounding results in horizontal scars • vertical scars result if the insect continues boring activity into the wood during a second year of its life cycle, resulting in an open J-shaped wound • attacks low-vigor trees, primarily in the lowest 5 m of bole • bark exfoliation may take 5 – 10 years • callus growth often conceals old damage	• increase the susceptibility of affected trees to wind breakage if the wounds do not callus over	• remove tree if wound is dark- faced • if wound is white-faced, tree is effectively compartmentalizing the wound and it can be retained
Frost crack seam (A)	• a tight seam on trunk	• seams can become infection courts for major defect-causing fungi	• if exhibiting leakage or stain then tree should be removed
Sunscald (A)	• a dead patch of wood indicating killed bark • caused by alternate warming of tissue (by sun's reflection from snow) during the day and freezing at night • primarily on younger, thin-barked trees on exposed sites (either southwestern exposure or in a low stocked stand)	• vigorous trees will grow new bark over the dead patch (although this may result in an infolded bark seam)	• retain tree, especially if exhibiting other signs of vigor
Black knot (B)	• black swelling on twigs and small branches • girdles twigs and small branches • infects black cherry	• severe infestations may create crown dieback symptoms, reducing competitive ability and response to release	• if more than 50 % of the crown is affected, it is considered a moderate defect
Severely leaning trees (A)	• tree leaning more than 10 ^{o} • root system may be exposed or partially exposed	• susceptible to windthrow, especially if some of their roots are above-ground or rotten • exposed trees (e.g., those on a ridge or edge of a stand) and shallow-rooted trees (resulting from a high watertable and shallow soils) are also prone to windthrow	• remove tree if quality is expected to continue to decline • removal of leaning tree will create a larger canopy opening than that produced by removal of a straight tree

[1]Two moderate defects on the same tree are considered a major defect.

Table 5.3.6: *continued*

Defect agent	How to identify	Effects on tree quality potential	Recommended action
Dead branch > 7.6 cm in diameter (A or B)	• dead branch (leafless) within the portion of the live crown that is > 7.6 cm in diameter	• indicates a vertical decay column of 0.2 to 1.5 m, depending on species (i.e., yellow birch has longer decay column than maple or beech)	• remove tree if quality is expected to continue to decline • trees with well-callused stubs, (if they are not swollen) indicate good vigor and should be retained • considered a minor defect if diameter of branch is < 7.6 cm
Dead top (A or B)	• dead tree top (leafless) • results from dieback, felling injury, or ice damage	• indicates potential top rot that is usually limited to the upper bole • stem stubs that are frayed or broom-like are highly probable sites for infection by major-defect causing fungi and indicate greater risk than do normal branches of similar size	• remove tree if break has removed > 75 % of crown • trees with the crown removed have some chance of survival; monitor recovery • if less than 50 % of crown has been removed, tree has good chance of survival
Root injury i.e., from harvesting damage (A)	• bark is sloughed from above-ground root portion, exposing wood underneath	• can predispose sugar maple to infection by root rot fungi and sapstreak • extensive root damage weakens tree, resulting in possible decline and windthrow	• root wound with > 25 % of roots exposed within the drip line of the tree crown is considered a moderate defect • to prevent injury follow careful harvesting practices outlined in **Section 8.3**

Table 5.3.7: Minor abiotic (A) and biotic (B) defects that reduce quality potential in hardwoods and recommended action. Trees with these defects will maintain quality over cutting cycle (AGS).

Defect agent	How to identify	Effects on tree quality potential	Recommended action
Burl (A)	• blemishes, often large, on side of stem	• arise from obscure origin and represent deformation of bole form • can result in a log grade defect if abundant, but do not indicate decay	• retain tree if it is not competing with better quality neighboring trees
Crook and sweep (A)	• entire stem or one log length of stem appears arched • probably caused by injury from another tree falling into stem during early years	• do not indicate decay	• retain tree if it is not competing with better quality neighboring trees
Epicormic branch (A)	• new branches that occur on the full length, or portions of the stem • caused by dormant buds on the stem that flush when stimulated by stress • often associated with a dying top	• may indicate additional problems (e.g., dieback) • usually a result of too little or too much sunlight	• retain tree if it is not competing with better quality neighboring trees

Table 5.3.8: Major, moderate and minor abiotic (A) and biotic (B) defects that reduce quality potential in conifers and recommended action. Defects are listed in decreasing order of priority for removal (from top to bottom).

	Defect agent	How to identify	Effects on tree quality potential	Recommended action
Most Damaging ↑	▪ Major defect—trees with these defects will degrade rapidly (UGS)			
	Fomes root rot (B)	▪ infects trees in previously thinned conifer plantations ▪ causes roughly circular patches of dead trees ▪ infected trees have thin, off-colored foliage	▪ spreads via root grafts and exposed surfaces (stumps and wounds) of any conifer ▪ trees will gradually decline then die	▪ remove infected trees ▪ stumps in plantations should be treated with borax during thinning operations
	Dead top (A or B)	see description for dead top in **Table 5.3.6**		
	Darkface scar > 968 cm^2 (A)	see description for darkface scar in **Table 5.3.5**		
	Butt barreling (B)	see description for butt flare, barreling in **Table 5.3.5**		
	Varnish conk (B)	▪ shelf-like conk with shiny reddish surface ▪ occur only on dying or dead trees (i.e., a scavenger rot) ▪ infects hemlock	▪ indicates decay	▪ remove infected trees
	▪ Significant defects—trees with these defects will degrade slowly (AGS), but are considered UGS if defect is severe			
	Porcupine feeding damage (B)	▪ feeding usually takes place high in the tree and girdling usually results in dead tops	▪ tree defect class will be either AGS or UGS depending on severity and position	▪ remove tree if UGS, otherwise retain
	Red ring rot (B)	▪ rust-brown shelf-like fruiting body sometimes located beneath a branch stub ▪ infection occurs through wounds, broken branch stubs and possibly branches damaged by white pine weevil	▪ causes a white pocket rot ▪ *P.pini* is the most common and causes extensive heart rot	▪ remove infected trees, unless required for seed production or crown closure
	Darkface scar < 968 cm^2 (A)	▪ see description for darkface scar in **Table 5.3.5**		
	White pine weevil (B)	▪ evidence of past damage is usually indicated by deformed stems	▪ tree defect class will be either AGS or UGS depending on severity and position	▪ maintain 50 % crown closure to protect establishing regeneration from weevil damage
	White pine blister rust (B)	▪ early stages: patches of yellow to orange bark ▪ later stages: swollen cankers on branches or trunk; heavy resin flow is usually associated with cankers	▪ tree defect class will be either AGS or UGS depending on severity and position	▪ remove tree if UGS, otherwise retain
	Crown dieback (B)	▪ see description for crown 50 % defoliated in Table 5.3.5		
	Pine bark beetle (B)	▪ male beetles cut holes through the bark to the wood where beetles constuct egg-laying galleries ▪ kills the vascular system of the tree	▪ is a major defect if found on the main stem, moderate if found on lateral branches ▪ smaller trees are killed quickly whereas on larger trees, branches are killed and cankers girdle the stem	▪ remove tree if feeding damage is found on main stem or if feeding damage is found on small-diameter trees

Table 5.3.8: *continued*

	Defect agent	How to identify	Effects on tree quality potential	Recommended action
↑	Lean >10 degrees (A)	• see description for severely leaning tree in **Table 5.3.6**		
	Root injury (A)	• see description for root injury in **Table 5.3.6**		
	• Minor defects—trees with these defects will maintain quality over cutting cycle (AGS)			• insect-damaged trees should be removed
	Crook and sweep (A)	• see description for crook and sweep in **Table 5.3.7**		
	Heavy branching (A or B)	• live crowns with many coarse, large-diameter branches	• trees usually have high taper and short log lengths (if any) and may have poor height growth • decreased wood quality because of large knot size associated with large-diameter branches	• retain tree if it is not competing with better quality neighboring trees
	Low fork (A or B)	• fork in main stem low in crown • frequently have large crowns that occupy excessive canopy space	• may develop infection courts from splitting • have a limited merchantable length	• retain tree if it is not competing with better quality neighboring trees
Least Damaging	High fork (A or B)	• fork in main stem high in crown	• susceptible to top breakage in windstorms • may develop infection courts from splitting	• removal of tree should be weighed against potential to provide nesting opportunities for a variety of bird species
	Narrow fork (A or B)	• frequently have lop-sided branching (large branches on one side) resulting in "D"-shaped stems	• trees usually have high taper and short log lengths	• retain tree if it is not competing with better quality neighboring trees

Summary of potential vigor, risk, and quality discussion

Table 5.3.9 summarizes the important points of the preceding discussion of potential vigor, potential risk, and potential quality for crop-tree selection.

Table 5.3.9: Guidelines for crop-tree selection (adapted from Anderson and Rice 1993).

Characteristic	Key features
Potential vigor	Potential vigor is likely to be high if: History • no recent stress events (e.g., defoliation, drought, frost, pollution) Autecological characteristics • species responds favorably to competition and release from competition Health • no serious infections or diseases High quality crowns • symmetrical, with numerous fine branchlets and twigs • half the crown or more is exposed to direct sunlight • crown diameter of 0.20-0.25 meters per centimeter of DBH • trees with multi-layered canopies are preferred to mono-layered trees • dense crown with no evidence of disease or injury Bark • firm bark, including plates and ridges • light color of new inner bark in base of furrows or smooth, peeling bark (for smooth-barked species)
Potential risk	Potential risk is likely to be low if: • no canker infections, insect borer wounds, beech bark disease, root infections, crown dieback or decline, severe leaning, forks, yellow-bellied sapsucker feeding holes, and crown damage from foraging black bears • low risk to windthrow, splitting, breakage of limbs due to tree location, condition, site features • high probability that tree will retain present quality for next 20 years
Potential quality	Potential quality is likely to be high if: • few, if any biotic indicators of decline • few, if any abiotic indicators such as broken or dead tops, burls, seams, scars, flutes, rot, shake, knots, stain

Tree classification systems

Tree classification systems combine information on potential tree vigor, risk, quality, and defect to produce a method of assessing crop-tree potential. They are used to determine which trees are selected for retention as residuals in selection harvesting operations.

Tree classification systems should recognize both current and potential quality. The current quality of many tolerant hardwood stands in southern Ontario does not necessarily reflect the capability of the sites on which they are growing. The “selective” nature of past logging (e.g., high-grading) and stem damage caused by fire, animals, and wood extraction are often directly responsible for present low quality (Anderson and Rice 1993).

Table 5.3.10 outlines a two-class system that classifies trees as either acceptable growing stock (AGS) or unacceptable growing stock (UGS). This system is usually adequate for stand improvement cutting operations, particularly in polewood stands (Anderson and Rice 1993).

Table 5.3.10: A simple two-class tree classification system for determining residual trees in tolerant hardwood forest cover types.

Tree Class	Class Description
Acceptable Growing Stock (AGS)	• Trees that contain or are potentially capable of producing high or medium quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop-tree producers of high quality sawlogs or veneer logs or sawlogs for dimension lumber (medium quality).
Unacceptable Growing Stock (UGS)	• Trees that have bole quality equal to AGS (described above) but that are of high risk or are expected to decline within a 20-year period. Often such trees are best harvested immediately. • Trees that contain or have the potential to produce low quality logs but no better. Such trees are often used for pulpwood, poker poles, bolter logs, or fuelwood but are not normally considered as crop trees. • Most cavity trees, specifically marked to be retained for their wildlife value • Cull trees with no sawlog potential, but that may be used for pulpwood or fuelwood if a market exists

An inventory that determines, at a bare minimum, the species composition, structure, and tree quality of the stand, should be conducted prior to preparing a prescription for improvement or harvest cutting operations. For marking hardwood stands that will be managed by selection silviculture systems, a tally sheet similar to the one shown in **Table 5.3.11** should be used. A minimum of 10, factor two prism sampling points (or sweeps) per stand is recommended, with one per hectare up to 30 ha and an additional point for every 5 ha over 30 ha. **Appendix C** provides basic guidelines for conducting prism sweep sampling.

Table 5.3.11: Stand analysis tally sheet for harvest or intermediate cutting.

STAND ANALYSIS FOR HARVEST OR IMMEDIATE CUTTING PAGE ____ OF_____	
LANDOWNER	FOREST COVER TYPE
TOWNSHIP	SIZE OF STAND
LOT, CONCESSION	SIZE OF FOREST (WITHIN WHICH THE STAND OCCURS)
AIR PHOTO ROLL #'s	ECOSITE VEG. TYPE
OBM#	SITE CLASS
DATE INSPECTED	INSPECTOR

STEP 1. CONDUCT STAND ANALYSIS TALLY	BY STATION, SPECIES, SIZE CLASS, AND QUALITY CLASS; RECORD # OF STATIONS IN BOX 1; MARK THEIR LOCATIONS ON AIR PHOTO

TREE SIZE CLASSES		POLEWOOD		SAWTIMBER								TOTAL	
		10 - 24cm		SMALL 26 - 36cm		MEDIUM 38 - 48cm		LARGE 50 - 60cm		X-LARGE 62 + cm		ALL 10 + cm	
STATION	SPECIES	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS

Table 5.3.11: *continued*

LANDOWNER	FOREST COVER TYPE
TOWNSHIP	SIZE OF STAND
LOT, CONCESSION	SIZE OF FOREST (WITHIN WHICH THE STAND OCCURS)
AIR PHOTO ROLL #'s	ECOSITE VEG. TYPE
OBM#	SITE CLASS
DATE INSPECTED	INSPECTOR

BOX 1: AS EACH STATION IS TALLIED RECORD THE TOTAL BA FOR THAT STATION IN THE EMPTY CELL BELOW THE NUMBERED CELL. LIST THE 3 DOMINANT TREE SPECIES IN ORDER OF ABUNDANCE.

1 *e.g,* 28	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MhMrAw														
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

STEP 2: CALCULATE BASAL AREA (SEE BOX 2 BELOW)

TREE SIZE CLASSES	POLEWOOD		SAWTIMBER								TOTAL	
	10 - 24cm		SMALL 26 - 36cm		MEDIUM 38 - 48cm		LARGE 50 - 60cm		X-LARGE 62 + cm		ALL 10 + cm	
	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS
BA												
BA total												

BOX 2: CALCULATE BA/HA (NOTE:BAF = Basal Area Factor of Prism)

TOTAL TREES (______________) X BAF ( ) = ( ) ACTUAL BA/ha

#OF STATIONS (FROM BOX 1)

STEP 3: CHOOSE AN IDEAL BASAL AREA (m^2/ha) DEPENDING ON LANDOWNER OBJECTIVES (TABLES 6.1.3 – 6.1.7). STRIKE OUT OTHER 3 ROWS.

TREE SIZE CLASSES		POLEWOOD	SAWTIMBER				TOTAL
		10-24cm	SMALL 26-36cm	MEDIUM 38-48cm	LARGE 50-60cm	X-LARGE 62+cm	ALL 10+cm
A	SITE REGION 6E SAWLOG IDEAL	4	5	6	5		20
B	SITE REGION 7E SAWLOG IDEAL	5	5	4	4	2	20
C	OLD GROWTH IDEAL	5	6	6	4	3	24
D	CLOSED CANOPY IDEAL	6	7	6	5	3	27

STEP 4: COMPARE IDEAL BASAL AREA (STEP 3) TO STAND'S BASAL AREA (CALCULATED IN STEP 2), AND DETERMINE TARGET BASAL AREA TO BE LEFT AFTER HARVEST.

TREE SIZE CLASSES	POLEWOOD		SAWTIMBER								TOTAL	
	10-24cm		SMALL 26-36cm		MEDIUM 38-48cm		LARGE 50-60cm		X-LARGE 62+cm		ALL 10+cm	
STATION	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS
BA												
BA total												

*** NOTE: TOTAL BA IN STEP 4 SHOULD BE NO LESS THAN 2/3 OF THAT IN STEP 2.**
*** NOTE: TOTAL AGS BA IN STEP 2 SHOULD BE > 9 m^2 / ha.**

Section 6
Silvicultural Guidelines by Forest Cover Types

INTRODUCTION

This section describes recommended silvicultural guidelines for the sustainable management of the seven forest cover types introduced and briefly described in **Table 5.1.2.** The ELC ecosites that correspond to each forest cover type are first described in greater detail in each of the following seven subsections. For each forest cover type, a brief comparison of presettlement and present day forest composition and structure follows in order to highlight some of the major changes that have occurred in the region, due primarily to human activities. An awareness of these changes could help landowners and managers to better recognize more natural forest cover and encourage them to set management objectives that consider the potential value of their stand (e.g., maintenance of a diversity of species and forest types; provision of forest cover of a certain age and structure, or wildlife habitat), to the larger landscape of tree species, forest types, and their associated wildlife species. Some might be encouraged to retain or work toward helping the recovery of more uncommon forest types and ages such as old-growth stands that have been largely lost from southern Ontario since early European settlement (Larson *et al.* 1999).

Then information about the autecology of the species comprising the forest cover type is presented, with an emphasis on the dominant species. How to choose an appropriate silvicultural system for the forest cover type follows in either table or decision-key format. Finally, the subsections provide specific instructions on the appropriate silvicultural systems that can be used to manage the forest cover type in southern Ontario.

Linking this guide to other OMNR silviculture guides

An analysis of OMNR Forest Ecosystem Classification plot data for southern and part of central Ontario revealed strong differences between vegetation communities in Site Regions 5E and 6E**.** However some overlap of communities does occur, primarily along the boundary between these two Site Regions (**Figure 4.1.6**). In southern parts of Site Region 5E where a milder climate and better site conditions provide more favorable growing conditions, vegetation communities more typical of Site Region 6E are found. Similarly, communities more commonly found in 5E occasionally occur in 6E where suitable climatic and site conditions exist.

The ecosite tables presented for each of the seven forest cover types in this section note similarities in vegetation communities between ecosites of southern (Site Region 6E) and central Ontario (Site Region 5E), where the analysis has shown them to exist (B. Chambers, OMNR, 1999, personal communication). Several OMNR publications: Chambers *et al.* (1997) and Lee *et al.* (1998) can provide more complete descriptions of the vegetation communities of these two Site Regions. This information is useful when applying silvicultural prescriptions developed for Site Region 5E and described in *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario* (OMNR 1998*a*) and *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* (OMNR 1998*b*), to appropriate ecosites and forest types in Site Regions 6E.

HARDWOOD FOREST COVER TYPES

In this guide, a forest with at least 75 % canopy cover in deciduous tree species (Lee *et al.* 1998) is considered a hardwood forest cover type. Percent canopy cover of hardwood species can readily be determined from 1:10,000 scale air photography. In southern Ontario, the most common deciduous species include sugar maple, red maple, silver maple, beech, basswood, white ash, green ash, red oak, white oak, black cherry, bitternut hickory, shagbark hickory, trembling aspen, largetooth aspen, and ironwood (Lee *et al.* 1998).

Deciduous forests are most common in southern Ontario where the climate is warmer and the growing season is longer. They are often found on a variety of soil types and topographic positions but generally grow better on well-drained soils where prevailing environmental conditions are not extreme.

Soil textures range from sand to clay; soil moisture regime ranges from dry (MR Ø, 0) to moderately moist (MR 4) for upland hardwood forests, moist to very moist (MR 5 to 6) for lowland hardwood forests, and wet (MR 7-9) for hardwood swamps; soil drainage classes range from very rapid (DR 1) to poor (DR 7). Moisture regime (MR) represents the seasonal available moisture supply for plant growth. Drainage class (DR) represents how quickly water percolates through substrates by gravitational flow, draining away to be no longer available for plant growth. The moisture regime and soil drainage class values used throughout this guide were developed by the Ontario Institute of Pedology and are further explained in their field manual for describing soils (Ontario Institute of Pedology1985).

Understory vegetation diversity is frequently quite high in deciduous stands because fertile soils and a milder climate provide favorable growing conditions. Also many understory plants are able to complete their growth before the hardwood canopy fully leafs out. In addition, when compared to mixed and coniferous stands, the lower density of trees in many deciduous stands allows a variety of understory vegetation to become established.

E. Boysen

6.1 UPLAND TOLERANT HARDWOODS

by Ken Elliott, Silvia Strobl and David Bland

Introduction

The term tolerant hardwood forest refers to stands primarily comprised of shade-tolerant deciduous trees. Mid-tolerant and intolerant species such as the oaks, ashes, yellow birch, black cherry, and poplars may also be found in these forests but normally do not form a dominant component**.** Across southern Ontario, numerous other species that either share dominance or are associated with sugar maple in these stands include American beech, Eastern hemlock, white pine, red oak, white oak, yellow birch, white birch, white ash, red maple, black maple, black cherry, basswood, ironwood, bitternut hickory, shagbark hickory, and butternut.

For the purposes of this guide, if the site inventory, briefly described in **Appendix C,** determines that sugar maple comprises more than 25 % (Lee *et al.* 1998) of the trees in the stand, then the stand can be described as a tolerant hardwood forest, and the silvicultural guidelines outlined in this subsection will provide recommendations for its management.

In southern Ontario, Site Region 7E generally provides the most favorable climate for most tolerant hardwood forest species because the growing season is longer and minimum temperatures are higher, than in other areas. Within 30 km of any of the Great Lakes, minimum temperatures and growing degree days are substantially higher, reducing the risk of early fall frost and lengthening the growing season by as much as 10 days (OMNR 1998*a*).

The most productive sites have relatively deep soils (i.e., at least one meter), typical of the tills and moraines of southern Ontario. Soils are slightly alkaline (e.g., preferred pH range is between 5.5 to 7.5; more acidic soils favor hemlock and yellow birch), developed from Paleozoic shales and limestones. Silty sands, sandy loams and fine loams with well-decomposed and incorporated humus materials are the most suitable soils for these species although fine sands and silt loams may be adequate if the moisture regime is satisfactory. Sites with coarse sands or heavy clays are usually less favorable.

Sugar maple, beech, and red oak grow best on sites with a fresh (MR 1-3) soil moisture regime; yellow birch and hemlock do well in very fresh to moist conditions (MR 3-5).

Local microclimate, influenced mainly by local aspect and slope, also affects site productivity. Protected upper slopes with good air drainage and southerly aspects encourage the development of vegetation characteristic of more southern regions; northern exposures and frost pockets favor more northern species. Southern exposures are hotter and drier than northern exposures, and in southern Ontario, these slopes may restrict hardwood growth because of soil drought conditions. Also hardwood stands on exposed ridges may experience winter sunscald damage, while stands on lower slopes with restricted air drainage, may suffer frost damage.

Key ecological factors that determine species associations in tolerant hardwood forests include soil type and depth, availability of moisture and sunlight, and proximity of seed sources and dispersal agents such as birds and mammals. Other important factors include past disturbance, land use, and management. For example, beech is an associated or codominant species in more mature stands without a recent history of disturbance. White birch and aspen tend to be common associated species on more recently and heavily disturbed sites; bitternut hickory and especially ironwood can become common associates on recently grazed sites. White ash is somewhat dependent on disturbance, and after thinning, can outgrow the more shade-tolerant sugar maple. Although its seedlings are shade-tolerant, it requires canopy gaps to persist in a stand and higher fertility (e.g., nitrogen and calcium) and moisture than sugar maple. Black cherry is another common associate that commonly develops following clear cuts, when its coppice and established regeneration can outgrow sugar maple. Logging tends to increase the black cherry component in a sugar maple-black cherry stand, but eventually this shade-intolerant species will die out if it does not receive enough sunlight.

Relatively pure stands of sugar maple are more common in central and southwestern Ontario and often have arisen from sugar bush management that removed all non sap-producing tree species. Sometimes such stands have developed due to the lack of available seed source for other species, or because of the superior shade tolerance and regeneration of sugar maple in these forests.

Forests dominated by sugar maple are the most common forest type in southern Ontario. The Ecological Land Classification Program (ELC) for southern Ontario (Lee *et al.* 1998) describes three ecosites in which this species can comprise more than 25 % of the stand. These three ecosites are briefly described below. A fourth ecosite, the dry-fresh deciduous forest ecosite, in which sugar maple represents less than 25 % of the composition is included in this section because selective management of some of these stands has the potential to increase the proportion of this species. The dry-fresh hardwood-hemlock ecosite is included here because it may be treated as an upland tolerant hardwood ecosite, especially the dry-fresh sugar maple-hemlock mixed forest type. Detailed fact sheets providing more information about these ecosites will be produced and distributed by the ELC program in the future.

Dry-fresh deciduous forest ecosite (FOD4)

This ecosite consists of relatively uncommon tree species associations that may have developed as a result of past management or disturbance. Sugar maple is absent from this ecosite or comprises less than 10 % of the canopy cover. It is included in this section because remedial silvicultural activities (e.g., thinning, improving soil aeration) over time could increase the proportion of sugar maple.

It is found growing on sands and loams. Normally it occupies upper to middle slopes or tableland topographic positions.

The ELC describes three deciduous forest types for this ecosite: beech, white ash, and hackberry. The latter type is rare in southern Ontario.

Dominant Trees	beech or white ash or hackberry (latter species in extreme southwestern Ontario)
Less Common Associates	varies by forest type
Common Shrubs	varies by forest type
Common Herbs and Ferns	varies by forest type
Soil Moisture Regime	moderate dry (MR 0) to fresh (1-3)
Soil Drainage	well-drained (DR 3) to moderately well-drained (DR 4)

Dry-fresh sugar maple deciduous forest ecosite (FOD5)

This ecosite commonly occurs on sands, coarse loams, and shallow (i.e., < 30 cm) soils over calcareous bedrock (e.g., sites above the Niagara Escarpment and on the lower talus slopes), and occasionally on fine loams. It is usually found on upper to middle slope or tableland topographic positions.

Limiting site conditions, proximity to a seed source, past disturbances (e.g., fire, windthrow), management (e.g., cutting, grazing, maple syrup operations), and current land use determine associated and codominant species. For example, oaks and black cherry are commonly found on slightly drier sites or where the site has been burned or cleared in the past. Ironwood is common on many sites with a history of grazing by livestock because this species is unpalatable to these animals. Proximity to a seed source can also help to determine the mix of associated species.

Sunlight is an important ecological factor because canopy closure is usually high in these forests. Canopy closure is usually greater than 80 %, except where occasional gaps occur from tree mortality or windthrow. As canopy closure increases, understory diversity (e.g., shrubs and herbaceous plants) usually decreases.

In general, tolerant hardwood forests represent a middle-aged to mature forest that occurs near the end of the successional sequence for a site. Perpetuation of tolerant hardwood stand composition is possible because these moderately to very shade-tolerant tree species are capable of regeneration and growth under shaded conditions that preclude the establishment of more intolerant species.

The ELC describes ten dry-fresh deciduous forest types in which sugar maple is a dominant or codominant species (Lee *et al.* 1998).

Dominant Trees	sugar maple and one or more of the following species: beech, red oak, white oak, ironwood, basswood, black cherry, bitternut hickory, shagbark hickory, white ash, red maple, white birch, trembling aspen, and large-tooth aspen
Common Shrubs	alternate-leaved dogwood, raspberry and red elderberry
Common Herbs and Ferns	trilliums, wild sarsaparilla, blue cohosh, and wild leek
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1-3) on upper to mid-slopes and tableland topographic positions
Soil Drainage	rapid (DR 2) to well-drained (DR 3)
Equivalent Ecosite in Central Ontario	ES24, 25 but bitternut hickory uncommon; lacking white oak, shagbark hickory (Chambers *et al.* 1997)

Fresh-moist sugar maple forest ecosite (FOD7)

This ecosite represents the transition between wetland swamp communities (i.e., moist moisture regime) and terrestrial communities (i.e., fresh moisture regime).

It is found on sands, loams, and rarely on clays. Soils may have an accumulation of organic material from 20 to 40 cm deep. Soil depth ranges from very shallow to deep. This ecosite is found on middle to lower slopes, bottomlands, and poorly-drained tablelands with complex microtopography.

On bottomlands, associated species that must compete well in moist soils include white elm, yellow birch, red and black maple, and green ash. With disturbance, green ash, white elm, and yellow birch can become more dominant because they are intermediate in shade tolerance and can outgrow the maples. Without disturbance, a mixed maple stand is likely to result on these sites.

On fertile, abandoned agricultural land, white ash is often a pioneer species, growing rapidly on moist sites. White elm and green ash are common associates on these sites and both do well in moist soil conditions. Sugar and/or red maple can invade these early successional ash stands, and over time become codominant species.

Basswood is a common associate on upland sites with soils of higher pH. This species grows well in alkaline conditions, and is found on the Canadian Shield, often where marble is the underlying bedrock. It is also common on the shallow soils of limestone plains, where it grows to a much larger size than the associated maple. Logging tends to increase the basswood component of a stand due to its ability to coppice.

The ELC describes five fresh-moist sugar maple deciduous forest types: sugar maple-lowland ash; sugar maple-black maple; sugar maple-yellow birch; sugar maple-white elm; and sugar maple-hardwood (Lee *et al.* 1998). The fresh-moist sugar maple-black maple deciduous forest is considered rare in southern Ontario.

Dominant Trees	sugar maple and several other codominants or common associates including green ash, black ash, red maple, white elm, basswood, yellow birch, and beech
Less Common Associates	in Site Region 7E, additional associates include sassafras, hackberry, and to a lesser extent, sycamore, tulip tree, pignut hickory
Common Shrubs	white elderberry, choke cherry, dwarf raspberry; spicebush in Site Region 7E
Common Herbs and Ferns	sensitive fern, spotted touch-me-not, ostrich fern, fowl manna grass, skunk cabbage, trilliums, Jack-in-the-pulpit
Soil Moisture Regime	fresh (MR 2,3) to moist (MR 4-6)
Soil Drainage	imperfect (DR 5) to poor (DR 6)

Dry-fresh hardwood-hemlock ecosite (FOM3)

This ecosite consists of hemlock with varying amounts of sugar maple, red maple, or red oak. Cover by shrubs and herbaceous vegetation, as well as species richness are low. It is found growing on sands and coarse loams, and, to a lesser extent, shallow substrates over bedrock and rock. Soils have finer silt and clay components. The moisture regime ranges from moderately dry (MR 0) to fresh (MR 1,2). This ecosite is typically found on slopes with adequate moisture and good drainage.

The ELC describes two forest types for this ecosite: dry-fresh hardwood-hemlock and dry-fresh sugar maple-hemlock mixed forest types.

Dominant Trees	hemlock, sugar maple, red maple, red oak
Less Common Associates	varies by forest type
Common Shrubs	varies by forest type
Common Herbs and Ferns	varies by forest type
Soil Moisture Regime	moderate dry (MR 0) to fresh (1,2)
Soil Drainage	well-drained (DR 3) to moderately well-drained (DR 4)
Equivalent Ecosite in Central Ontario	ES 28 and ES 25 (Chambers *et al.* 1997)

Changes since the presettlement era

The presettlement tolerant hardwood forests of southern Ontario most likely had different species composition (e.g., a larger hemlock and pine component; a smaller mid-tolerant species component) and structure (e.g., more layers of vegetation; larger woody ground debris) than most of the remaining stands exhibit today. In addition they contained species that are far less common today (e.g., American chestnut, American elm). Some of these differences are discussed below in more detail.

Different species composition

In southern Ontario the species composition of the tolerant hardwood forest today differs substantially from forests encountered by the early settlers (**Section 4.2**).

More hemlock and pine

Many tolerant hardwood forests probably had a larger component of white pine and hemlock during presettlement times until the early European settlers heavily harvested these species (Elliott 1998). From the notes of the first land surveyors, Keddy (1993) found that hemlock-white pine and sugar maple-white pine forests dominated areas in eastern Ontario underlain by Precambrian bedrock. Clay plains were covered most often by sugar maple-American elm forests, but basswood, white pine and balsam fir were also relatively widespread. Limestone and till plains were dominated by sugar maple and beech with elm, basswood and hemlock associates; sand plains were dominated by hemlock and sugar maple forests with occasional associations of a variety of other species.

These historical stand compositions have implications for forest management in the region today. On suitable sites, landowners and managers should try to retain and encourage the regeneration of white pine and hemlock. **Section 6.5** (for the pine forest cover type) and **Section 6.7** (for the hemlock forest cover type) provide silvicultural information for enhancing or maintaining pockets of these species within tolerant hardwood stands.

Fewer mid-tolerants

Today the overstory of many tolerant hardwood forests contains scattered intolerant and mid-tolerant hardwood species, while the understory vegetation consists almost entirely of sugar maple and beech. These large canopy trees originated during the late 1800s or early 1900s, after forests were cleared. Such land clearing was often associated with increased frequency of fire that was often started by railways. Subsequent abandonment of the land due to changing commodity prices or production efficiency enabled these species to gradually attain dominance. Like other tolerant hardwood stands in many parts of eastern North America, stands in southern Ontario, have a higher frequency of less shade-tolerant species, in particular oak species, as a result of such human intervention (Abrams 1996).

Again, this change in species composition over time has implications for management. Owners or managers who want to regenerate these mid-tolerant species within the tolerant hardwood forests of southern Ontario should be aware of the higher associated costs of silvicultural intervention and the greater risk of failure, compared to management of these stands for tolerant hardwoods. On many sites, management for mid-tolerant species such as oaks will require silvicultural understory treatments to remove the advanced maple and beech regeneration by either herbicide or prescribed burn treatments, as well as overstory treatments to open the canopy and stimulate regeneration of the desired, more light-demanding species.

Moreover, high quality seed sources for the desired mid-tolerant species may not be available, due to the fragmentation of the surrounding landscape. Also, in many parts of southern Ontario the small forest remnants may not provide enough intermixing of pollen, or supply enough seed rain to regenerate the desired mid-tolerant species. In addition, these smaller forested tracts are more susceptible to invasion by non-native species that may prevent natural regeneration of desirable species or successfully compete with desired crop trees (e.g., common buckthorn). Higher levels of desiccation in some of these forest fragments may also lead to a high degree of seed crop failure.

Structural differences

The focus of much current forest science research is on understanding old-growth forest ecosystems. This has led to a better understanding of forest structure and how it has changed over time. Some studies compare the composition and structure of remnant old-growth stands with that of secondary or managed stands in similar climatic and soil conditions. Researchers have found that the structure and composition of managed and old-growth stands vary in the amount of large-diameter size trees, snags, cavity trees, and downed woody debris, and the size of canopy gaps. Some of these structural differences are discussed below.

More large-diameter trees

Studies of old-growth stands in Upper Michigan found that they differed from younger stands with similar composition and site conditions in several ways. About half the canopy of these older stands was occupied by trees larger than 45 cm DBH; one-third of the canopy was comprised of mature trees (25 – 44 cm), and the remainder was occupied by gap saplings and poles (Frehlich 1995).

More snags (>30 cm DBH)

Snags are standing dead trees. Many species (e.g., hawks and owls) rely on them for habitat. In the northern hardwood forest, Goodburn and Lorimer (1998) found an average of 12 snags per hectare with diameters greater than 30 cm DBH in managed stands while old-growth stands contained 22 snags per hectare. The highest densities of snags with a diameter greater than 30 cm DBH occurred in old-growth hemlock-hardwood stands and averaged more than 40 snags per hectare.

More cavity trees (> 45 cm DBH)

Cavities are hollows in living or dead trees that usually form following injury to the tree or excavation by woodpeckers and allow wildlife access to their interior. Cavities made by primary excavators (e.g., woodpeckers) are used by other species and thus can help to increase wildlife diversity of a stand. Goodburn and Lorimer (1998) found on average 11 cavity trees per hectare in managed stands and 17 cavity trees per hectare in old-growth stands.

More downed woody debris (>10 cm DBH)

Goodburn and Lorimer (1998) also discovered that the volume of fallen wood (> 10 cm in diameter) was significantly lower in managed uneven-aged stands (average volume of 60 m^3/ha) than in old-growth stands (average volume of 99 m^3/ha). Volume differences were even more pronounced for large diameter debris (> 40 cm in diameter).

More variation in gap sizes, including a few bigger gaps

In the presettlement old-growth tolerant hardwood forests, a variety of canopy gap sizes would have occurred naturally as a result of tree falls, windstorms, and severe downbursts. Some larger gaps are critical to regenerate species with low shade tolerance and maintain tree species diversity in a stand. Clebsch and Busing (1989) compared community structure in a secondary growth stand and adjacent old-growth stand in a southern Appalachian cove forest. They found gaps in the former tended to be small (< 100 m^2) and had little regeneration of intolerant species. Individual gap microsites were not markedly different from the understory as a whole. Gaps in the old-growth stand were larger and had higher light microsites that contrasted sharply with the shaded forest floor. They concluded that the wider range of gap sizes in old-growth forests accommodates a variety of species, including intolerant species, and contributes to higher canopy species diversity.

In secondary growth stands, canopy gaps were less than a quarter of the size of those in old-growth stands because the fallen trees (known as "gap makers") had smaller diameters. Gap makers in younger stands generally had a ratio of gap-maker DBH to mean DBH of canopy trees of less than 1.0 as compared to greater than 1.5 for old-growth stands. Gap makers in younger stands were disproportionately from minor species such as ironwood while those in old-growth stands were predominantly from the dominant canopy species. Even in old-growth forests, most gaps were small (mean 44 m^2) and created by single trees (Dahir and Lorimer 1996).

More old-growth forest

Old-growth stands are much less common than they were at the time of early or presettlement and only small remnant stands exist today in much of northeastern North America. For example, in a 56,000 acre remnant of "pristine" landscape in Upper Michigan, old-growth stands dominated 70 % of the area while polewood and mature stands occupied 9 % and 21 % of the area, respectively (Frelich 1995). This finding suggests that presettlement forest cover was predominantly in an old-growth state.

A more extensive network of old-growth forest preserves is needed as insurance against loss of these endangered ecosystems by catastrophic windstorms or other large-scale natural disturbances (Webb 1999). In the fragmented forest landscape of southern Ontario perhaps the best hope is to encourage the management of existing stands to develop old-growth structural conditions. Our understanding of eastern old-growth forest ecosystems has increased dramatically over the past decade as a result of research into their history, composition, structure and associated processes, and will no doubt continue to improve (Davis 1996). Also using existing old-growth stands as a benchmark could provide the basis for some additional modifications to single-tree selection prescriptions that should enhance biodiversity protection, at least at the stand scale.

Choosing an appropriate silvicultural system

The selection of the most appropriate silvicultural system for the management of tolerant hardwood forests is based on several factors:

- an understanding of the autecology of the desired species
- site potential or capability
- the current stand structure, composition, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed below.

Autecology of sugar maple

Some knowledge of the natural history of sugar maple, the dominant species in tolerant hardwood forest cover types, can help to improve the likelihood of successful silvicultural management. Important biological information (adapted from OMNR 1998*a*) for sugar maple is listed below. **Table 6.1.1** summarizes autecological characteristics for 13 of the most common species of this forest cover type. Refer to **Appendix B** for detailed information on the autecology of the principal species of the tolerant hardwood forests of southern Ontario.

Table 6.1.1: Autecology of common species in the tolerant hardwood forest cover type (Burns and Honkal 1990*a* and 1990*b*).

Species	Sugar maple	Beech	Yellow birch	Hemlock	Red oak	White ash	Basswood
Site	Most site types, prefers well-drained loams	Fresh, well-drained, fresh loamy soils with high humus content	Well-drained, fertile loams, moderately drained sandy loams	Fresh soils with good drainage	Well-drained, fresh, loam-silt loam	Moderately well-drained, fertile soils	Moderately fresh sandy loams-silt loams
Canopy openings to secure regeneration or growth	Variety	Single-tree	Tree height group or uniform canopy (40-50%)	Uniform canopy (70%) or single-tree	Uniform canopy (60-70%)	Variety	Tree height group or uniform canopy (40-50%)
Seed periodicity	3-7 years	2-8 years	1-4 years	2-3 years	2-5 years	3-5 years	1-2 years
Seedbed type	Mineral-organic mix	Mineral soil, leaf litter	Mineral soil, humus	Mineral-humus mix, burned duff, decaying wood	Mineral soil, humus, mineral-humus mix; best if covered with light layer of leaf litter	Mineral soil, humus	Mineral soil, humus mix
Sprouting ability	Good	Good	Poor	Very poor	Very good	Good	Very good
Likelihood of advanced regeneration	High	High	Low	Moderate-high	Low (upland sites only)	Moderate-high	Moderate
Shade tolerance	Very tolerant	Very tolerant	Intermediate	Very tolerant	Intermediate	Intolerant (shade-tolerant at seedling stage, decreases with age)	Intermediate-tolerant (increases with age)
Tending need	Crop tree	Crop tree	Crop tree	Seedbed	Competition	Crop tree	Crop tree
Self-pruning	Good	Moderate	Good	Poor	Moderate	Good	Very good
Response to release	Very good	Moderate	Moderate (dieback, if excessive)	Very good (dieback, if excessive)	Moderate (poles and saplings only)	Good (dominant, codominant crown classes only)	Good (dominant, codominant crown classes only)
Rot/stain defect	High	High	High	Low	Moderate-low	Low	Moderate
Bole/form defect	Fork	Epicormics	Fork	Shake	Epicormics	Fork	Sweep
Decline hazard	Moderate	Moderate	Moderate-high	Moderate-high	Moderate-high	Moderate-high	Moderate
Growth rate	Slow-moderate	Slow	Moderate	Slow	Moderate-fast	Moderate-fast	Moderate-fast
Wildlife values	Mature forest cover, cavity sites, browse	Mast, raptor nesting sites, cavity sites	Catkins, raptor nesting sites, browse	Winter wildlife cover, browse, mast	Mast, wildlife browse	Mast, wildlife browse	Mast, wildlife browse, cavity sites

Table 6.1.1: *continued*

Species	Black cherry	Butternut	Bur oak	White oak	Bitternut hickory	Red maple
Site	Deep, well-drained sandy loam-loam	Stream bank sites, well-drained soils	Shallow over limestone; tolerates wide range of soil and moisture conditions	Wide range of soils and sites	Well-drained uplands, variety of soil types	Wide range of soils and sites
Canopy openings to secure regeneration or growth	Tree height group, larger openings; uniform canopy (30-40%)	Tree height group	Uniform canopy (60%)	Uniform canopy (60%)	Uniform canopy (60%)	Variety
Seed periodicity	1-5 years	2-3 years	2-3 years	4-10 years	3-5 years	1-2 years
Seedbed type	Humus	Litter	Disturbed litter	Humus	Litter	Mineral soil
Sprouting ability	Very good	Moderate	Poor	Very good	Very good	Very good
Likelihood of advanced regeneration	Low-moderate	Low	Common under thinned plantations	Low-moderate	Low-moderate	Moderate-high
Shade tolerance	Intolerant	Intolerant	Intermediate	Intermediate	Intolerant-intermediate	Tolerant (decreases with age)
Tending need	Competition	Competition	No data	Competition	No data	Competition
Self-pruning	Good	Good	Moderate	Moderate	Moderate	Good
Response to release	Poor (dieback if excessive)	Poor	No data	Very good (poles and saplings only)	No data	Very good
Rot/stain defect	Moderate	High	Low	Low	Low	High
Bole/form defect	Sweep	No data	Branching, epicormics	Branching, epicormics	Forking, branching	Fork
Decline hazard	Moderate-high	High	High (serious decline caused by canker, oak wilt)	No data	No data	High
Growth rate	Moderate	Fast	Slow	Slow	Slow	Fast-moderate
Wildlife values	Mast	Mast; frequently used as a den tree	Mast	Mast	Mast	Wildlife browse

Reproduction and early growth

Sugar maple has several competitive advantages over its associates including:

a) *Seeds and germination*
- Some seed is produced most years with good seed crops produced every two to five years.
- Seed dispersal occurs in the fall, usually prior to leaf fall, and has an effective range of up to 300 m in a strong wind.
- Seeds germinate at low temperatures, often before snow is completely melted, thereby getting an earlier start in the spring than most other species.

b) *Site factors*
- A vigorous radicle that easily penetrates matted, deep layers of undisturbed leaf litter.

c) *Early growth*
- Very tolerant of shade, requiring only five per cent of full sunlight.
- Early survival is enhanced by shade, resulting in prolific advanced growth of small seedlings (e.g., 150,000 to 200,000 seedlings/ha).
- High mortality of seedlings under heavy shade (e.g., 50 % mortality over three years).

d) *Other*
- Reproduces readily by stump sprouts and vigorous sprouts from small stumps (<15 cm DBH) have the potential to produce high quality stems if properly thinned.

Reaction to competition

- Completes its seasonal growth earlier in the year, allowing it to take advantage of sunlight early in the season.
- Has a lower light requirement for optimal photosynthetic activities than most other species.
- It can withstand suppression for many years.
- It responds well to release at nearly all ages; annual height growth (following release) of up to 90 cm and ring widths of 10 mm.
- Excessive release of suppressed trees up to 20 cm DBH often promotes development of epicormic branches from dormant buds; as stand density increases again, these branches often die within 8 years.
- Reproduces aggressively by seedling sprouts in excessively opened stands (<9 m^2/ha residual basal area), resulting in even-aged regeneration that must be tended if regeneration of other mid-tolerant species (e.g., oaks) is preferred.
- Is shade-tolerant with vegetative reproduction more tolerant than seedlings.

Factors limiting growth and development

- *Excessive moisture:* In wet areas, changes in drainage or water table levels can restrict root aeration and either restrict growth rates or cause mortality.
- *Thin soils or shallow-capped drumlin landforms:* The relatively deep and branching root system present on well-drained soils cannot develop on thin soils and consequently increases risk of windthrow of stems on these sites

- *Ice storms:* The large crowns of dominant and codominant sugar maple stems are vulnerable to damage from ice loading.
- *Fire:* Very susceptible to fire damage.
- *Environmental*: Road salt harms sugar maple.
- *Insects:* Defoliation by leaf-feeding insects, primarily forest tent caterpillar, occurs cyclically, and not only reduces growth, but depletes food reserves, resulting in mortality in case of successive infestations; potentially high mortality of sugar maple could result if Asian long-horned beetle is introduced to southern Ontario (this insect has infested urban trees in Chicago and New York City).
- *Disease:* Punk knot accounts for about one-third of infections and volume loss; other parasitic fungi that can kill maples include target and cobra cankers (see **Table 5.3.5**).
- *Browsing:* Winter browsing by deer on seedlings and saplings may cause severe damage and can even prevent re-establishment on some sites (e.g., Rondeau Provincial Park).
- *Poor management:* Heavy sap-tapping operations and poorly organized stand harvesting (**Section 8.3**) can reduce the quality of residual stems and result in infection by decay fungi. Cattle grazing prevents recruitment and can damage tree roots.
- *Drought:* A few years of drought can cause losses of previously stressed trees.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber or other forest products (e.g., maple syrup). If not, the stand is better left alone to provide other values such as wildlife habitat.

The site potential or capability helps to determine the silvicultural system of choice. Site quality assessment is an evaluation of soil characteristics (e.g., texture, drainage, fertility, depth), topography (e.g., aspect, elevation), climate, and other factors that influence growth and species composition, and ultimately provide an indication of the suitability of a site for the growth of certain species or forest types. This assessment is essential to determine the amount of effort required to manage a stand for tolerant hardwoods.

Current stand structure, composition, and condition

Silvicultural options vary for even-aged and uneven-aged tolerant hardwood stands. Therefore managers must determine stand composition and structure, and current age-classes and condition of the stand. Also they must know what species are desired in the stand after harvest operations. Often, accurate assessment of stand structure, composition, and conditions not only suggests the most suitable silvicultural system for a tolerant hardwood stand, but also enables more precise predictions of potential growth rates and yield estimates.

Knowledge of current stand condition is particularly important in southern Ontario because the natural structure and composition of so many stands have been disrupted by past forest management, grazing, diameter-limit cutting, and high-grading. Therefore, the inventory should include an assessment of stand quality (e.g., by using the tally sheet in **Table 5.3.11**).

In many stands, initial management for commercial purposes should be directed first at improving stand structure and quality; removing diseased, defective, and other inferior trees; and improving species diversity and composition. For example, if the inventory reveals that the mature stand contains less than 9 m^2/ha in AGS trees, then a regeneration cut (uniform shelterwood system) could be used to remove the high proportion of lower quality and defective trees, and quickly promote regeneration from the better quality residual trees. As regeneration develops stand quality will improve, and single-tree selection may be preferable. A poor understanding of the initial condition of these disturbed forests, however, can lead to unrealistic targets and management objectives.

Wildlife habitat and other natural heritage values

The tolerant hardwood forests often support many wildlife habitats, as well as rare species, and other important forest values. **Section 4.4** and **Tables 4.4.1**, briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Landowners and managers have opportunities to manage and/or improve several of these habitats through relatively simple modifications of the recommended silvicultural systems for tolerant hardwood forests. This is a worthwhile undertaking because such prescription adjustments will often encourage sustainable wood harvest and the maintenance of other forest values.

Important guidelines for the management of these specific wildlife habitats are briefly described below.

Leave more large-diameter trees

Landowners and managers who are more interested in creating and protecting wildlife habitat and less concerned about optimizing economic return should consider retaining more basal area in an extra-large sawlog-diameter size class (i.e., >60 cm DBH). For example, maintaining 2m^2/ha in this class is equivalent of leaving four, 80 cm DBH trees per hectare.

Recent studies from southwestern Ontario (McCracken 1999) suggest that some forest interior bird species, including the endangered Acadian flycatcher, the vulnerable cerulean warbler**,** as well as American redstart, hooded warbler, wood thrush, veery, and scarlet tanager prefer to nest in parts of the forest with a high basal area of large-diameter trees. This finding suggests there may also be some advantage to maintaining large and extra-large-sawlog size trees in close proximity to each other if conservation of these birds is to be successful.

Leave some snags (>30 cm DBH)

Selection practices that continually remove so-called defective trees from the stand will reduce the amount of available habitat for cavity nesters and numerous other species that have been little studied. Adding a retention target for snags (where these trees do not interfere with timber removal or worker safety), should not greatly diminish stand productivity since tolerant hardwood stands managed for optimum sawlog production had only a quarter of the natural mortality of similar stands where no selection thinning occurred (Eyre and Zillgitt 1953). Therefore much of the management for optimum sawlog production is focused on capturing (through timely thinnings) the approximately 75 % of lost growth that naturally dies in the tolerant hardwood forest, before it dies. In the Greater Fundy Ecosystem, forest management guidelines recommend a minimum of 12-15 snags per hectare with a diameter greater than 20 cm (Woodley and Forbes 1997). In stands with few or no snags, managers and landowners can create them by girdling a few trees.

Leave some cavity trees

On Crown Land in Central Ontario, tree-markers must retain at least six cavity trees of at least 25 cm DBH per hectare and at least one cavity tree per hectare that is at least 40 cm in DBH. Cavity trees are chosen on the basis of the following order of priority (Naylor *et al.* 1996):

1. Pileated woodpecker roost or nest trees.
2. Trees with nest cavities of other woodpeckers or natural nest or den cavities.
3. Trees with escape cavities.
4. Trees with feeding excavations.
5. Trees with the potential to develop cavities.

Refer to **Section 4.4** and **Table 4.4.1** for more specific information concerning guidelines for retention of cavity trees. These guidelines could be adopted for use on private property in southern Ontario. With at least 50 species of cavity nesters known to occur in the forests of southern Ontario, there is good reason to leave a larger number of cavity trees per hectare.

Retain some conifer cover

Patches of conifers such as pines, hemlock, and cedar should be retained because they provide important winter cover for many birds and mammals. In addition, bigger trees provide nest and roost sites for larger birds such as eagles, hawks, and wild turkeys. **Table 4.4.1** recommends guidelines for retaining conifer cover.

Retain some mast-producing species

Many species, including beech and ironwood, two trees commonly found in tolerant hardwood forests, as well as oaks, hickories, black walnut, and butternut produce nuts that are eaten by many animals. Therefore landowners and managers should refer to the discussion of specialized wildlife habitats **(Section 4.4)** and **Table 4.4.1** for recommended retention guidelines.

Leave downed woody debris (>10 cm DBH)

Although it may be difficult to incorporate a target for downed woody debris (DWD) in tree-marking prescriptions, leaving a target number of snags should over time increase the amount of DWD. Leaving defective portions of logs in the bush instead of dragging them to the landing and using careful logging practices that minimize disturbance to the forest floor could also increase the amount of DWD.

Create a few larger gaps

Landowners and forest managers should recognize that in many tolerant hardwood stands, the exclusive use of single-tree selection creates mostly small canopy openings that will gradually increase the composition of sugar maple. Larger openings of up to two canopy tree heights in size (i.e., up to approximately 60 m in diameter) should be created to encourage regeneration of other associated tree species that require more sunlight (**Tables 6.1.10**). Several researchers (Kurzava and Mladenoff 1999; Clebsch and Busing 1989; Dahir and Lorimer 1996) have found mean gap size to be significantly larger in old-growth stands than in polewood and mature stands, and somewhat more numerous in mature stands.

Many tree and shrub species with low shade tolerance are important to a variety of wildlife because they produce food in the form of nuts and berries. However, except for beech and ironwood, most mast-producing species (e.g., oaks, hickories, basswood, black cherry, butternut, black walnut, honey locust, tulip tree, red mulberry, eastern flowering dogwood, and American chestnut) are less shade-tolerant than maple. On Crown Lands in central Ontario, tree-markers are required to retain seven to eight mast trees (> 25 cm DBH) per hectare. Similar guidelines could be adopted for use on private land in southern Ontario. However, where mast-producing trees are either mature or very old, forest managers should encourage the establishment of regeneration by providing the necessary light and moisture requirements (**Appendix B**).

Protect sensitive understory vegetation

Changes in understory vegetation species composition and abundance can occur in uncut woodlots as a result of abiotic (e.g., increasing shade) and biotic factors (e.g., competition, browsing by deer). For example, Reader (1987) found an average of 6 to 11 % of herbaceous species and 3 to 10 % of woody species disappeared from uncut tolerant hardwood plots, one year after vegetation sampling.

Two studies in southern Ontario (Reader 1987; Williams and Bricker 1992) reported that selection harvesting had little or no effect on forest understory species richness and abundance. Reader (1987) found no significant change in the percentage of herbaceous species lost one year after tree harvesting, regardless of tree-cutting intensity (0 %, 33 %, 66 % basal area removal) or area treated (12.5 m, 25 m, 50 m plot diameters). The 66 % basal area removal and larger gap size would correspond to a shelterwood or group selection treatment while the 33 % basal area removal and smaller plot sizes (12.5 m and 25 m) would correspond to a single-tree selection treatment.

Following selective tree harvesting, Reader (1987) also observed that species with low abundance were more likely to be lost from a tolerant hardwood forest understory than more abundant species. The most likely cause of species disappearance was soil disturbance from skidding of logs and moving equipment. To avoid damage or loss, plants of conservation concern (e.g., the endangered American ginseng, threatened golden seal, rare hart's-tongue fern, showy orchis, puttyroot), should be well marked before harvesting activities begin. Furthermore activities should not disrupt the site conditions they require for survival (e.g., level of shade or soil moisture).

Reader (1987) discovered that common spring-flowering herbs with tuberous roots (e.g., bloodroot, yellow dog's-tooth violet, hepaticas) showed no response to the levels of tree-cutting intensity described above, suggesting that the winter timing of tree harvesting does not negatively affect the underground root meristems of these common spring herbaceous species. This result is not surprising since these species actually complete most of their growth before the trees leaf out. Toothworts, host plants for the rare West Virginia white butterfly, also showed little or no change in abundance one to three years after harvesting in another southern Ontario study (Williams and Bricker 1992).

The increased light intensity and soil disturbance associated with tree harvesting often provides suitable environmental conditions for species normally associated with open, disturbed areas (e.g., raspberry, Virginia creeper and riverbank grape). For example, Williams and Bricker (1992) reported a small increase in the abundance of summer-flowering herbs both one year and three years after harvesting in 19 tolerant hardwood forest stands in three study areas located in Grey County, Dufferin/Simcoe Counties, and Halton/Peel Regions on the Niagara Escarpment. On some sites (e.g., smaller woodlots; woodlots in urban areas; woodlots with a high edge-to-interior ratio), invasive, non-native species (e.g., buckthorns, several honeysuckles, barberry, privet, autumn olive) can take advantage of small canopy gaps created by single-tree selection. Invasion is more likely if soil disturbance accompanies the logging. Effects can be lessened by careful winter harvest.

Therefore before considering any silvicultural treatment that will increase sunlight intensity and soil disturbance, landowners and managers must consider the location and size of the forest stand in relation to the surrounding landscape. Small isolated woodlands are more susceptible to invasions by invasive, non-native and native plants, as well as to windthrow, drought, disease, and insect infestations (Pearce 1992).

In most situations, the preferred silvicultural systems and their respective treatments are those that most closely mimic natural ecological processes and lead to the most natural stand composition and structure, with minimal disruption to the site.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of tolerant hardwood stands.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood system and suggest the use of a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Recommended silvicultural systems for upland tolerant hardwoods

According to Anderson and Rice (1993), when sites are managed for high quality timber production and the maintenance or enhancement of other forest values, silvicultural options are determined by the shade tolerance of the crop species to be managed and the quality composition of the stand under consideration. They suggest that single-tree selection is an option for high value timber production on appropriate sites with shade-tolerant species (e.g., hard maple, beech, hemlock), but only if the stand is of sufficient quality to sustain acceptable levels of value growth over a number of cutting cycles.

In southern Ontario, it is primarily tolerant hardwood forest stands occurring on productive soils that are managed by uneven-aged silviculture systems. Uneven-aged management is preferable because sugar maple seedlings readily establish themselves and develop in the understory of openings (i.e., gaps in the canopy) created by harvest, and a permanent cover of large trees is maintained. Moreover, uneven-aged management through the use of selection systems represents a compromise between maintaining rapid diameter growth rate and promoting high quality. For example, even-aged management of sugar maple can produce merchantable sawlog heights of one to one-and-a-half logs, but the same species managed in uneven-aged stands can yield merchantable sawlog heights of two to two-and-a-half logs (Erdmann 1986). Finally, uneven-aged silvicultural selection systems somewhat resemble natural disturbances such as wind and ice storms that kill only one or a few mature trees and create canopy gaps in the tolerant hardwood forests of southern Ontario.

On some sites, the group selection system may be suitable to perpetuate some mid-tolerant crop species. This silvicultural technique removes trees in small groups, opening the canopy more than with single-tree selection. It should be considered if appropriate site and other conditions necessary for regeneration of less shade-tolerant species exist. Group selection is also appropriate in stands that support populations of the threatened hooded warbler, a forest interior species which prefers to nest in the dense thickets of early successional vegetation that commonly occupies forest gaps following disturbance by windthrow or selection logging (Friesen *et al.*, in prep.).

However, in the fragmented forests of southern Ontario, forest managers need to balance the objective of creating gaps to regenerate mid- to intolerant canopy tree species with the objective of maintaining closed canopy forest interior bird habitat. Also, forest managers must be aware of the overall size of contiguous forest in which gap openings are planned. If gaps are created in small, isolated forests they may create disturbance conditions ideal for invasion by exotic species from neighboring woodlots.

On sites where maintenance of intolerant or mid-tolerant crop species is the primary objective, and where these species comprise 50 % or more of the stand, or where stand quality is not sufficient for selection (e.g., the stand was high-graded), the uniform shelterwood system may be more appropriate.

Due to ecological and aesthetic concerns, and the shade tolerance of some of the species of tolerant hardwood forests, the use of the clearcut system in southern Ontario is usually discouraged by most forest managers and therefore is not generally recommended. However, the use of small clearcuts does provide the best method of maintaining pockets of intolerant tree species (e.g., poplar, white birch) that may be found within tolerant hardwood forests, should this be a management objective. See **Section 6.4** for more details on this option. In southwestern Ontario where so little forest cover remains, managers are encouraged to reforest old field sites to produce intolerant hardwood stands, rather than clearcut existing forests to maintain this forest cover type.

Table 6.1.2 presents an overview of stand conditions and management objectives that can influence the choice of a silvicultural system for use in tolerant hardwood forests. Three options, single-tree selection, group selection, and uniform shelterwood are discussed in greater detail in the remainder of this subsection.

Table 6.1.2: Choosing an appropriate silvicultural system for tolerant hardwood forests in southern Ontario.

	Single-tree selection	Group selection	Uniform shelterwood
Existing stand conditions	• on sites with a major component of shade-tolerant species, mainly hard maple and capacity to respond to release at relatively advanced ages (OMNR 1998*a*) • stand has a minimum of 9 m^2/ha in trees 9 cm DBH and larger (or 7 m^2/ha in trees 24 cm DBH larger) of crop quality (OMNR 1998*a*) • risk of invasion by exotic shrubs and herbs (e.g., buckthorns, garlic mustard) is high	• overstory contains groups of defective or overmature trees and management for old-growth characteristics is not desired • intolerant and mid-tolerant species (e.g., basswood, white ash, oaks, yellow birch, black cherry, hickories, tulip tree) comprise 10 to 40 % of the stand composition and site and stand conditions are suitable for regeneration and growth of these species • risk of invasion by exotic shrub or herbaceous vegetation is low	• intolerant or mid-tolerant tree species comprise 50 % or more of the stand (primarily basswood or white ash) • pockets of even-aged red oak/white pine exist within the stand • stand quality is not sufficient for application of the selection method, regardless of species composition • risk of invasion by exotic shrub or herbaceous vegetation is low
Objectives for stand	• to produce high quality wood products • to maintain forest interior habitat throughout stand • to minimize aesthetic and environmental impacts of harvesting (provided that logging damage is minimized) • to provide conditions for developing old-growth characteristics	• to maintain up to 50 % regeneration of intolerants and mid-tolerants (Leak *et al.* 1987) • to reduce logging damage to residual growing stock during periodic cuts • to encourage better tree form • to improve certain wildlife habitat (e.g., for the threatened hooded warbler) or increase its diversity within the stand • to remove patches of low quality trees in only one periodic cut • to increase economic viability of sale preparation and logging	• to convert to or maintain an even-aged stand • to replace a decadent, unhealthy, or otherwise unproductive overstory • to encourage mid-tolerant species in suitable portions of stands being managed under the selection system

Single-tree selection system

Introduction

The single-tree selection system is generally recommended for mature upland tolerant hardwood stands where the site and stand conditions are appropriate to sustain uneven-aged tolerant forests. It is especially suited for mature stands dominated by hard (sugar and black) maple and when minimal disruption of the existing forest ecosystem and natural succession are primary objectives.

Assessing stand potential for management by single-tree selection

It is sometimes difficult to assess the potential of a mature stand to respond favorably to management by single-tree selection. Managers will want to know current stocking levels (i.e., number of trees/ha and basal area in m^2/ha) of all trees and crop-quality trees (i.e., AGS), by DBH class as determined from the stand inventory and subsequent compilation of a stand stocking table (**Table 5.3.11**). Stands should have a minimum of 9 m^2/ha in trees 9 cm DBH and larger, or 7 m^2/ha in trees 24 cm DBH and larger of acceptable growing stock (AGS), in order to properly apply single-tree selection management.

Some mature stands with a basal area of AGS quality stems below the minimum threshold (i.e., less than 7 m^2/ha in trees of 24 cm DBH and larger) have little potential for management by the single-tree selection system. However, some of them may be regenerated using the uniform shelterwood system to re-establish shade-tolerant overstory species or encourage the development of a new stand consisting of fewer shade-tolerant species.

Concerns with single-tree selection

Although single-tree selection is the least intrusive silvicultural system, a number of problems can develop if it is not properly implemented. Used over time, this system creates conditions favorable to shade-tolerant species (e.g., sugar maple). Therefore, to conserve species diversity, landowners and managers should look for opportunities to retain some mid-tolerant species if they currently exist in the stand. For example, some mid-tolerant species could be retained as mature trees or their regeneration could be promoted by creating some larger canopy gaps in adjacent portions of the stand, especially where these species occur as advanced regeneration.

Personal bias of landowners, managers, and tree-markers can also influence the species composition of stands managed under single-tree selection. For example, some harvesting operations in the past heavily reduced populations of ironwood and beech because of their low timber value (Elliott 1998). While discouraging beech and ironwood is desirable where they dominate a stand (e.g., on poorly managed stands), it is important to maintain in stands, some of these and other species with little or no commercial value. This is especially important because the long-term impacts on the forest and its inhabitants, of selectively removing these and other species with no merchantable value, are unknown and unstudied. Beech produce nuts that are eaten by many wildlife species and its tendency to decay in the trunk creates long-lasting cavities of value to numerous forest animals. Ironwood buds are an important winter food source for ruffed grouse and other animals. Also retention of other species (e.g., smaller trees such as flowering dogwood, blue beech; shrubs) adds structural complexity to a stand and increases biodiversity. It is also good common sense not to reduce biodiversity by managing for only one or two species.

Improperly implemented single-tree selection systems may result in incomplete thinning among polewood and small sawlog size classes, or the total removal of the large sawlog size class.

To minimize potential concerns and improve the probability of achieving management objectives, silvicultural prescriptions for single-tree selection in tolerant hardwood stands should include *specific* instructions regarding:

- silvicultural objective(s) for the forest stand
- target residual stand basal area, and distribution by diameter-class
- how to determine the target basal area and amount to thin
- crop-tree selection and marking
- treatment of polewood stems
- treatment of advance regeneration
- timing of operations
- specific wildlife habitats concerns

Each of these topics is discussed in the following.

Silvicultural objective(s) for the forest stand

Single-tree selection prescriptions will vary slightly depending on landowner objectives for the stand and site and stand conditions. This guide provides four sets of ideal residual basal areas by diameter-class for the implementation of single-tree selection prescriptions. Additional prescriptions that accommodate a different maximum DBH size, a shorter than eight- to 20-year cutting cycle, or a higher total basal area can be derived by anyone familiar with q-values and their calculation.

When thinning stands with a greater proportion of mid-tolerant species and a smaller component of a sugar maple, a higher total basal area (e.g., more than 21 m^2/ha) can be left following a single-tree selection harvest. Also, stands on highly productive sites (i.e., deep sandy loams, loamy sands, silt loams) can usually support a higher total basal area than the 21 m^2/ha target recommended for sawlog production.

As noted in the discussion of stand structure for uneven-aged stands in **Section 5.2**, adhering to the recommended ideal basal areas for each diameter-class will ensure a balance of age and size classes of trees in the stand, permitting a sustainable intermittent harvest of some high quality, larger diameter stems in a sustainable fashion.

In this guide, the four sets of ideal residual basal area recommendations are referred to by three names that correspond to typical landowner objectives shown in **Table 6.1.3**.

Target residual stand basal area and distribution by diameter-class

The reader should be familiar with the discussion in **Section 5.2** about stand structure as it applies to uneven-aged stands. **Tables 6.1.4** to **6.1.7** provide ideal residual basal area by diameter distributions for tolerant hardwood stands for the three sets of landowner objectives outlined in **Table 6.1.3**.

Depending on species mixture, local site quality, and Site Region, mature tolerant hardwood stands can obtain stocking levels substantially higher than those recommended in **Tables 6.1.4** to **6.1.7**. A recent survey of 37 potential old-growth woodlots in southern Ontario found basal area averaged 36.0 m^2/ha (Larson *et al*. 1999). **Table 7.2.2** also suggests that substantial gross merchantable volume (GMV) increment can continue to accrue in even-aged stands with high (e.g., > 30 m^2/ha) basal area.

Table 6.1.3: Recommended single-tree selection residual basal areas for different landowner objectives.

Landowner objectives (in order of priority)	Recommended ideal residual basal area
Sawlog production	
1. to maximize high quality sawlog and veneer production 2. firewood production (to make use of trees that must be removed if the number of sawlogs is to be increased) 3. to maintain and/or improve wildlife habitat	• See **Table 6.1.4** for ideal residual basal area recommendations by diameter-class for Site Region 6E and **Table 6.1.5** for Site Region 7E
Develop old-growth characteristics	
1. develop structural characteristics that more closely approximate old-growth or presettlement conditions 2. improve wildlife habitat conditions, especially for forest interior birds 3. some sawlog and firewood production	• See **Table 6.1.6** for ideal residual basal area recommendations by diameter-class • Also see "Suggested modifications for unique stand conditions--Management of tolerant hardwood stands to provide uneven-aged old-growth structural characteristics"
Maintain old-growth characteristics and a closed canopy	
1. maintain existing old-growth characteristics (e.g., large-diameter trees, downed woody debris) 2. minimal disturbance to wildlife habitat 3. minimal sawlog and firewood production	• See **Table 6.1.7** for ideal residual basal area recommendations by diameter-class. • Also "Suggested modifications for unique stand conditions--Management of tolerant hardwood stands to provide uneven-aged old-growth structural characteristics"

Table 6.1.4: Recommended residual stocking after cutting (trees per hectare) by diameter class for <u>maximizing sawlog production</u> for Site Region 6E.
(total residual basal area = 20 m^2/ha; maximum DBH = 60 cm*; q-value = 1.1, based on 2 cm DBH classes)

Size Classes	DBH (cm)	Trees (#/ha)	BA m^2/ha	Trees (#/ha)	BA m^2/ha	Ideal BA m^2/ha
Polewood (10-24 cm)	10	31.3	0.25	183.9	4.00	4
	12	28.5	0.32			
	14	25.9	0.40			
	16	23.5	0.47			
	18	21.4	0.55			
	20	19.5	0.61			
	22	17.7	0.67			
	24	16.1	0.73			
Small Sawlog (26-36 cm)	26	14.6	0.78	70.1	5.16	5
	28	13.3	0.82			
	30	12.1	0.85			
	32	11.0	0.88			
	34	10.0	0.91			
	36	9.1	0.92			
Medium Sawlog (38-48 cm)	38	8.3	0.94	39.5	5.63	6
	40	7.5	0.94			
	42	6.8	0.94			
	44	6.2	0.94			
	46	5.6	0.94			
	48	5.1	0.93			
Large Sawlog (> 50 cm)	50	4.7	0.91	22.3	5.21	5
	52	4.2	0.90			
	54	3.8	0.88			
	56	3.5	0.86			
	58	3.2	0.84			
	60	2.9	0.82			
Total		315.8	20.00	315.8	20	20

* A 60 cm maximum DBH was used to calculate the numbers in the table, but it does not mean that trees cannot be grown larger than 60 cm DBH.

Table 6.1.5: Recommended residual stocking after cutting (trees per hectare) by diameter class for maximizing sawlog production for Site Region 7E.
(total residual basal area = 21 m^2/ha; maximum DBH = 70 cm*; q-value = 1.125, based on 2 cm DBH classes)

Size Classes	DBH (cm)	Trees (#/ha)	BA m^2/ha	Trees (#/ha)	BA m^2/ha	Ideal BA m^2/ha
Polewood (10-24 cm)	10	37.5	0.29	205.8	4.34	4
	12	33.3	0.38			
	14	29.6	0.46			
	16	26.3	0.53			
	18	23.4	0.59			
	20	20.8	0.65			
	22	18.5	0.70			
	24	16.4	0.74			
Small Sawlog (26-36 cm)	26	14.6	0.78	66.6	4.87	5
	28	13.0	0.80			
	30	11.5	0.82			
	32	10.3	0.82			
	34	9.1	0.83			
	36	8.1	0.82			
Medium Sawlog (38-48 cm)	38	7.2	0.82	32.9	4.65	5
	40	6.4	0.80			
	42	5.7	0.79			
	44	5.1	0.77			
	46	4.5	0.75			
	48	4.0	0.72			
Large Sawlog (> 50 cm)	50	3.6	0.70	16.3	3.77	4
	52	3.2	0.67			
	54	2.8	0.64			
	56	2.5	0.61			
	58	2.2	0.59			
	60	2.0	0.56			
X-Large Sawlog (> 62 cm)	62	1.8	0.53	7.1	2.37	2
	64	1.6	0.50			
	66	1.4	0.47			
	68	1.2	0.45			
	70	1.1	0.42			
Total		328.7	20.00	328.7	20	20

* A 70 cm maximum DBH was used to calculate the numbers in the table, but it does not mean that trees cannot be grown larger than 70 cm DBH.

Table 6.1.6: Recommended residual stocking after cutting (trees per hectare) by diameter class for <u>developing old-growth</u> structural characteristics for Site Regions 6E and 7E.
(total residual basal area = 24 m^2/ha; maximum DBH = 70 cm*; q-value = 1.13, based on 2 cm DBH classes)

Size Classes	DBH (cm)	Trees (#/ha)	BA m^2/ha	Trees (#/ha)	BA m^2/ha	Ideal BA m^2/ha
Polewood (10-24 cm)	10	48.0	0.38	260.0	5.48	5
	12	42.4	0.48			
	14	37.6	0.58			
	16	33.2	0.67			
	18	29.4	0.75			
	20	26.0	0.82			
	22	23.0	0.88			
	24	20.4	0.92			
Small Sawlog (26-36 cm)	26	18.0	0.96	81.5	5.95	6
	28	16.0	0.98			
	30	14.1	1.00			
	32	12.5	1.01			
	34	11.1	1.00			
	36	9.8	1.00			
Medium Sawlog (38-48 cm)	38	8.7	0.98	39.2	5.52	6
	40	7.7	0.96			
	42	6.8	0.94			
	44	6.0	0.91			
	46	5.3	0.88			
	48	4.7	0.85			
Large Sawlog (> 50 cm)	50	4.2	0.82	19.0	4.37	4
	52	3.7	0.78			
	54	3.3	0.75			
	56	2.9	0.71			
	58	2.6	0.67			
	60	2.3	0.64			
X-Large Sawlog (> 62 cm)	62	2.0	0.60	8.0	2.68	3
	64	1.8	0.57			
	66	1.6	0.54			
	68	1.4	0.50			
	70	1.2	0.47			
Total		407.7	24.00	407.7	24	24

* A 70 cm maximum DBH was used to calculate the numbers in the table, but it does not mean that trees cannot be grown larger than 70 cm DBH.

* Trees up to 120 cm DBH may occur.

Table 6.1.7: Recommended residual stocking after cutting (trees per hectare) by diameter class for <u>maintaining old-growth</u> structural characteristics for Site Regions 6E and 7E.
(total residual basal area = 27 m^2/ha; maximum DBH = 70 cm*; q-value = 1.13, based on 2 cm DBH classes)

Size Classes	DBH (cm)	Trees (#/ha)	BA m^2/ha	Trees (#/ha)	BA m^2/ha	Ideal BA m^2/ha
Polewood (10-24 cm)	10	54.0	0.42	292.6	6.14	6
	12	47.7	0.54			
	14	42.3	0.65			
	16	37.4	0.75			
	18	33.1	0.84			
	20	29.3	0.92			
	22	25.9	0.98			
	24	22.9	1.04			
Small Sawlog (26-36 cm)	26	20.3	1.08	91.7	6.69	7
	28	18.0	1.11			
	30	15.9	1.12			
	32	14.1	1.13			
	34	12.4	1.13			
	36	11.0	1.12			
Medium Sawlog (38-48 cm)	38	9.7	1.11	44.0	6.23	6
	40	8.6	1.08			
	42	7.6	1.06			
	44	6.8	1.03			
	46	6.0	0.99			
	48	5.3	0.96			
Large Sawlog (> 50 cm)	50	4.7	0.92	21.1	4.92	5
	52	4.1	0.88			
	54	3.7	0.84			
	56	3.2	0.80			
	58	2.9	0.76			
	60	2.5	0.72			
X-Large Sawlog (> 62 cm)	62	2.2	0.68	9.0	3.02	3
	64	2.0	0.64			
	66	1.8	0.60			
	68	1.6	0.57			
	70	1.4	0.53			
Total		458.4	27.00	458.4	27	27

* A 70 cm maximum DBH was used to calculate the numbers in the table, but it does not mean that trees cannot be grown larger than 70 cm DBH.

* Trees up to 120 cm DBH may occur.

Determining the target basal area and amount to thin

The amount of thinning will depend on realistic stocking targets that are based on a compromise between the existing stand structure determined by an inventory (**Table 5.3.11**), and the **ideal** basal area by diameter-class set, chosen from the three sets previously described.

To determine the **target** basal area, one important rule is that no more than one-third of the total basal area within a stand should be removed in one cutting operation. Removing more than this increases the risk of reducing timber quality in subsequent harvests (OMNR 1998*a*).

Initial thinning is often directed at achieving residual basal area targets, as well as at improving stand structure and quality by removing trees of poorer quality. This stand improvement may be continued as required during future cutting. Sometimes this thinning may also be applied to improve the tree species composition of a seriously degraded stand. A few typical examples follow.

- In a stand with a history of cattle grazing, the abundant ironwood may be heavily thinned to encourage the return and regeneration of other species such as sugar maple, white ash, or yellow birch.
- Heavily stocked stands (e.g., total basal area > 30 m^2/ha) with crop-quality trees in excess of ideal stocking and well above the minimum threshold value, could receive an improvement cut that would harvest most UGS trees and lightly thin the AGS trees in the DBH classes showing a surplus basal area (i.e., more than is recommended in the ideal basal area set).
- Stands stocked below recommended levels (i.e., poorly-stocked stands), consisting largely of lower quality trees and a lower basal area of crop-quality AGS trees, may not produce high quality timber unless a significant proportion of low quality or declining trees are removed. These trees could be removed in an improvement cut thereby reducing the basal area. All AGS trees, except those whose removal is required to improve spacing, could be retained, and the stand could be managed on a 20-year rotation. Retention of some of the better unacceptable growing stock (UGS) stems might also be required to maintain stand density targets or to avoid decreasing stand basal area by more than one-third (Anderson and Rice 1993) as shown in **Figure 5.2.5**.

In stands where the protection and/or enhancement of wildlife habitat is an important management objective, stocking targets may have to be adjusted accordingly to ensure that initial and subsequent stand thinnings retain and/or encourage the future development of important habitat features such as mast tree species, cavity trees, and pockets of conifers. Cutting cycles may also have to be altered to affect desirable change in wildlife habitat. For example, a cutting cycle greater than 20 years would increase the number of cavity trees in many stands. In order to maintain optimum tree growth and tree health through a cutting cycle, an increase in cutting cycle usually also means a corresponding decrease in the targeted residual basal area. To ensure optimum growth and health of the stand the cutting cycle, residual basal area, and maximum DBH are all related; changes to one have an impact on the others. When wildlife habitat management objectives conflict with timber management objectives (e.g., a nest tree of a raptor is adversely affecting growth of a tree with high potential value), decisions that favor wildlife habitat protection instead of timber production will likely help to better sustain other forest values as well.

Crop-tree selection and marking

Normally the selection of crop trees is based on the potential vigor of the tree (i.e., the relative capacity of a tree to increase in size), potential risk of the tree dying or significantly deteriorating over a given time period, and potential quality of the tree in terms of timber value (**Section 5.3**).

To maximize economic and other forest values for a stand, crop-tree selection should only be undertaken by certified tree-markers. Securing the advice and services of these professionals is also recommended because some municipalities are now considering the modification of their tree bylaws to specifically require that tree marking by OMNR-certified markers precede all tree harvesting operations.

Treatment of polewood stems

Thinning of polewood size-classes is necessary on productive sites dominated by tolerant hardwoods. Polewood thinning should provide an opportunity to move polewoods into the main canopy where eventually they will maintain a relatively dominant crown position capable of continued satisfactory growth. But such thinning should still maintain stocking in polewood clumps to ensure continued self-pruning to the lower 7.5 to 10 meters of bole. Polewood-sized trees benefit most from thinnings that leave no more than 14 to 26 m^2/ha of total basal area (OMNR 1998*a*), and removes poorer quality trees.

Treatment of advanced regeneration

On productive sites dominated by hard maple, thinning of sapling classes is unnecessary. In uneven-aged stands, especially those dominated by hard maple, abundant advance regeneration is commonly present on the forest floor so no specific instruction need be specified in the silvicultural prescription. However, if the inventory indicates presence of advanced regeneration of less shade-tolerant species, especially of rarer species that occur in Site Region 7E, the prescription might specify that tree marking in these areas should try to create improved light conditions to release this advanced regeneration.

Timing of operations

Table 8.3.3 provides a list of the advantages and disadvantages of harvesting during different seasons, and should be consulted before scheduling harvesting operations. Summer logging will disrupt nesting and breeding wildlife, may decrease reproductive success of forest interior birds if the stand is being used by these wildlife species, and can cause serious damage to actively growing trees, shrubs and herbaceous plants.

Specific wildlife habitat concerns

The occurrence of any specific wildlife habitats listed in **Table 4.4.1** should be noted in the silvicultural prescription and the recommended actions suggested in this table should be followed.

Suggested modifications for unique stand conditions

Management of tolerant hardwood stands to provide old-growth characteristics

Silvicultural objective

- to use a modified selection system to develop or maintain old-growth characteristics in high quality, uneven-aged tolerant hardwood stands while allowing periodic timber harvest
- to maintain a closed-canopy condition with residual basal area usually higher than 21 m^2/ha

The purpose of managing for old-growth forest characteristics is to retain or restore a component of late-successional, uneven-aged tolerant hardwood forest for wildlife habitat, recreational, and educational values, as well as to produce some larger diameter-class veneer quality, specialty timber products. This objective is achieved through protection (i.e., no harvest in some forest stands and Areas of Concern) and management of selected tolerant hardwood stands for the following old-growth characteristics:

- irregular, uneven-aged age-class distribution with a high proportion of large stems
- average overstory diameter of approximately 51 cm (20 in.) with trees greater than 46 cm (18 in.) occupying about 45-50 % of the canopy; trees from 25-45 cm occupying about 25-33 % of the canopy; and the remaining 17-30 % occupied by saplings and poles
- high incidence of snags, fallen logs, and cavity trees
- large conifers (e.g., white pine, hemlock)

Site description

Selected sites should exhibit above-average productivity to avoid excessive mortality in larger trees that are retained and ultimately to ensure commercial viability of this prescription. Sites should also have an abundance of large trees. For more information see the Extension Note *Restoring Old-Growth Features to Managed Forests in Southern Ontario*.

Silvicultural prescription

Management should be designed to closely mimic gap-phase mortality patterns and to minimize logging disturbance because studies of old-growth forests suggest that major stand-replacing fires or windstorms were relatively rare on upland loamy sites. Instead, small gaps were created by the fall of one to several large trees, resulting in the creation of a forest of shade-tolerant species with canopy openings of varying sizes, for example 0.004 to 0.04 ha (0.01 to 0.1 acre) and a range of age classes.

Two recommended ideal basal area distributions by diameter-class are given in **Tables 6.1.6** or **6.1.7**, and should be used as a basis for determining the target basal area. Also adherence to the following additional guidelines should help to develop old-growth structural conditions:

- Leave 2.3 m^2/ha (10 ft^2/acre) of large culls or standing snag trees.
- Follow all den and wildlife tree marking guidelines, giving particular attention to cavity trees and large conifers, primarily hemlock and white pine, and protection or enhancement of white pine and hemlock regeneration on suitable microsites. See **Table 4.4.1** for specific guidelines.
- Aim for the size class distribution in **Tables 6.1.6** or **6.1.7.**
- To reduce the amount of canopy opening, consider removing no more than one-quarter of the basal area.
- To minimize disturbance to the site, regeneration and standing trees, restrict harvest operations to frozen ground conditions and strictly follow the guidelines for careful harvesting provided in **Section 8.3.**
- Long-butting of cull logs should occur at the stump to enhance the supply of downed woody debris.

Management of young hardwood stands to produce high quality sawlogs

Silvicultural objective

- to use a modified selection system in young even-aged hardwood stands to release 124 to 185 crop trees per hectare (50 to 75 crop trees per acre) thereby focusing site resources on the best trees available to produce high value trees that are free of defects, with long, straight stems and no branches for the lower 5 to10 m of their length

Management seeks to accelerate the natural growth potential of young hardwood stands resulting in earlier sawlog production than would normally occur without silvicultural intervention.

Site description

Selected sites should exhibit at least average site productivity and support even-aged stands of 20- to 60-year-old trees (the younger the better) of good potential quality (e.g., 60 % AGS trees). For more information see the Extension Note *Managing Young Hardwood Stands for Sawlog Production*.

Description of silvicultural prescription

Silvicultural management in young tolerant hardwood stands involves the selection of a variety of different species of potentially valuable crop trees that will maintain stand diversity and provide a possible hedge against the vagaries of local markets. Usually species of high value such as oak, ash, maple, cherry, or yellow birch are selected. However, any species that is well adapted to the stand conditions can be managed in this manner.

The stand is thinned initially at some time before the live crown ratio drops below 40 %. Each crop tree should receive a full crown release by eliminating adjacent trees that touch the crop tree crown by cutting or by killing these trees through girdling or herbicides. Thinning around crop trees by this crown-touching method is best applied soon after canopy closure, when codominant trees average 7.6 to 9.1 m tall.

Care must be taken not to thin too much. Some competition with other trees is needed to encourage the growth of tall, straight, unforked stems, and to inhibit the growth of lower branches. If too many trees are removed, new (epicormic) branches may sprout along the stems of the remaining trees, possibly reducing their future value.

Crown release in young stands can increase DBH growth of individual trees by 30 to 50 % for five to 10 years after treatment (Lamson and Smith 1989 *in* Miller *et al.* 1998). In addition, release treatments can be planned to favor selected species and promote a gradual improvement in species composition as the stand matures.

Stands are thinned again every 10-15 years until trees reach a marketable size (i.e., when average stem diameter is 25-35 cm). At this time some trees are harvested and the remaining stems provide seed sources to gradually convert the stand to an uneven-aged tolerant hardwood forest (i.e., by the group or single-tree selection system). However, if the species and site are more suited to even-aged management, continue crop-tree thinning until it is time to regenerate the stand by the shelterwood system.

Landowners and managers should realize that older, even-aged stands with average stem diameters greater than 25 cm may not benefit from crown-touching thinning. Therefore it is wise to seek professional advice before cutting older, even-aged stands.

Specifics of silvicultural prescription

Specific silvicultural treatments concerning the selection, release, and harvest of crop trees in young, even-aged hardwood stands are provided below.

<u>Crop-tree selection</u>

- In general, select crop trees as described above under “Crop-tree selection”. Potential crop trees are identified by their crown position, bole quality, risk, and sometimes, stem origin (Anderson and Rice 1993).
- Select vigorous, dominant trees with one-third of their total height consisting of live crown.
- Begin marking crop trees 10 to 20 m inside the stand.
- Mark individual trees at approximately 7 m intervals along parallel transects, positioned about 7 m apart. At each seven-meter stop, mark the closest crop tree within a 1.5-2.0 m circle, or best tree in vicinity since crop tree quality is more important than spacing.

<u>Crop-tree release</u>

1st thinning:

- Begin crop-tree release when crowns of adjacent trees start to touch each other, usually when the stand is 15- to 20-years-old and stems average 15 cm in diameter.
- Do not thin coarse-branched species (e.g., oaks, ashes) until they are 25- to 40-years-of-age or about 20 cm in diameter.
- Thin the stand by using the average stand diameter as determined from the inventory and the recommended stocking levels shown in **Table 6.1.8**.
- Do not thin sparsely stocked stands.
- In mixed-species stands, cut all trees that are not crop trees, but that have crowns in the overstory canopy that touch the crown of a crop tree.
- Treat two crop trees that are close together as one tree.
- Cut unhealthy, low quality, leaning, forked, or cankered trees between the marked crop trees to reach desired stocking levels provided in **Table 6.1.8**.
- Thin dense pockets of trees of roughly equal quality, retaining those with the best-developed crowns, particularly for fine-branched species such as black cherry and yellow birch.

Table 6.1.8: Recommended stocking guide for even-aged tolerant hardwood stands.

Average stem diameter DBH (cm)	Number of crop trees per hectare at rotation	Total number of trees per hectare		Total basal area per hectare (m^2/ha)	
		Average	Maximum	Average	Maximum
15	200 to 220	835	920	14.5	16.2
17		720	790	16.3	17.9
19		600	670	17.0	19.0
21		515	570	17.8	19.7
23		450	500	18.6	20.7
25		390	425	19.2	20.9
27	140 to 180	355	390	20.3	22.3
29		315	350	20.7	23.1
31		290	320	21.9	24.1
33		260	290	22.2	24.8
35		230	260	22.2	25.0

2nd (and subsequent) thinning(s):

- Thin the stand every 10 to 15 years until the average stem diameter reaches 25 to 35 cm.
- In the second thinning, reduce the total number of trees in the stand to 230-390 per hectare, with about 140-180 of these trees as crop trees, spaced approximately 7.5-8.5 m apart.
- At this stage, release each crop tree from only two competitors in the main canopy (i.e., on only two sides).
- Retain some adjacent trees for their potential to produce at least medium-quality sawlogs.
- Remove unhealthy or undesirable species but maintain the recommended stocking levels shown in **Table 6.1.8**.
- As the stand matures, seek advice for managing and harvesting older stands and converting the stand to an uneven-aged stand structure.

Management of degraded tolerant hardwood stands that have been grazed by livestock

Silvicultural objective

- to use a modified selection system to improve species composition (e.g., reduce an unnaturally large ironwood component) and accelerate currently absent seedling, sapling, and polewood in-growth in tolerant hardwood stands previously grazed by livestock

Site description

These hardwood stands are readily identified by:

- predominance of graze-tolerant species such as ironwood and also beech seedlings less than 30 cm tall
- absence of sugar maple (and other hardwood species) in the middle-age classes (e.g., sapling and polewood), indicating a past period of intensive grazing that prevented growth of these species into larger size classes
- sparse herbaceous understory; predominance of dog tooth violet and/or spring beauty (Drummond and Keddy 1996) in the understory, two spring ephemeral species that can withstand considerable grazing pressure

Silvicultural prescription

The first management priority should be to establish and maintain fencing that prohibits further grazing in the woodlot. Then the potential for stand management should be determined by evaluating the following factors:

- the potential of the site to respond favorably to selection management (e.g., is basal area of AGS trees favorable?)
- site productivity
- whether the stand is uneven or even-aged
- presence of shade-tolerant species
- presence of seed sources

- the quality composition of the stand (i.e., is it of adequate quality to sustain acceptable levels of value growth over a number of cutting cycles?)

Management should be designed to reduce the ironwood component, or other over-abundant tree species, to promote regeneration of desirable tolerant hardwood species, and improve soil aeration and moisture content.

- Choose the appropriate sawlog production ideal basal area-diameter distribution to determine the target basal area-diameter distributions for the stand. Realize that the stand will be deficient in sapling and polewood for at least one, if not two cutting cycles, but maintain enough of a sawlog component to meet the total basal area specified in **Table 6.1.4** or **Table 6.1.5**.
- The sapling and polewood components should be thinned and spaced with a focus on improving quality and reducing the proportion of ironwood and beech. A basal bark herbicide application can be used (**Section 8.1**). Do not remove the entire ironwood component.
- In heavily compacted areas, cut up some ironwood saplings to use as wooden stakes to drive into the ground to increase aeration. Stakes should be driven in as deep as possible and at a density of one stake per square meter.
- Consider supplemental planting with native tree species to speed restoration of appropriate species diversity for the site.
- Where species composition is limited or where natural regeneration is having difficulty becoming established, consider supplemental planting with native understory plants. Do not dig these from other forested areas (except under the limited conditions listed in the Extension Note "*Successful Transplanting of Woodland Vegetation for Plant Salvage or Habitat Restoration Projects*"); rather use a reputable native plant nursery (e.g., as recommended in SER-Ontario Chapter 1999).

Group selection system

Introduction

The group selection system is recommended for application in upland tolerant hardwood stands in the following situations:

- to provide sufficient sunlight in stands with a high proportion of mid-tolerant or intolerant species (e.g., white ash, yellow birch, basswood, red oak, black cherry) for their successful regeneration and development, but where single-tree selection clearly would discourage their regeneration and development by promoting a highly shaded environment more favorable to the tolerant species such as sugar maple and beech
- to accelerate the rate of conversion of even-aged stands (i.e., that originated from a clearcut) to an all-aged condition
- to improve degraded or simplified stands with little hard maple, beech, or hemlock, by encouraging the re-establishment of these shade-tolerant species
- to promote or maintain specific wildlife habitat (e.g., small canopy openings within a large, contiguous forest to support hooded warbler habitat requirements) (Friesen *et al.* 2000)

This silvicultural system is **not** recommended for use in tolerant hardwoods:

- to encourage the development of uneven-aged stands consisting primarily of mid-tolerant species
- to exclusively manage for oak species in the group opening (the shelterwood system is a better choice if this is the management objective)
- that require substantial improvement cutting (e.g., high-graded stands). These should be treated for improvement first, with fewer group selection openings or none until the next cutting cycle (Miller *et al.* 1995).
- where its application would jeopardize significant wildlife habitats (e.g., raptor nesting habitat, winter conifer cover, area sensitive forest interior bird habitat, especially for endangered species like Acadian Flycatcher, or the habitat of rare shade-tolerant plant species such as American ginseng or golden seal)

If properly applied, the group selection system is intended to regenerate even-aged patches of mid-tolerant trees at appropriate locations within a stand that is being managed primarily for shade-tolerant species using single-tree selection. For example, in many parts of southern Ontario, irregular topography and drainage patterns create varying site and stand conditions within a frequently encountered tolerant hardwood forest classified by the southern Ontario ELC system as the dry-fresh sugar maple deciduous forest ecosite (FOD5). Often red oak, white oak, white pine, and/or black cherry are found on the ridges with shallow, drier soils (ELC dry-fresh red oak deciduous forest type). Basswood and yellow birch may grow in the pockets of deeper, moister soil at the base of these ridges (ELC moist/fresh basswood deciduous forest type). A mosaic of even-aged patches of mid-tolerant species within this ecosite could be encouraged if managers create group openings on the ridges and in the moist pockets that provide favorable conditions for the regeneration of oak, basswood, and yellow birch.

Silvicultural prescriptions for group selection in tolerant hardwood stands must include:

- specific instructions for harvest regulation
- the size, number of, and shape of openings
- location of openings
- thinning treatments between openings
- treatment of advanced regeneration in the group openings
- timing of harvesting operations
- specific wildlife habitat concerns
- follow-up requirements

Each of these aspects is discussed in the following.

Harvest regulation

When implementing group selection prescriptions, resource managers risk over-harvesting unless they make a conscious effort to consider and pre-plan the size and number of canopy gaps created, and the residual basal area of the areas between gaps. The amount to be harvested can be regulated by area control, basal area control or volume control. For each method, managers must establish appropriate targets for residual basal area and stand structure **(Tables 6.1.4 to 6.1.7).**

The area method of harvest regulation is recommended where harvesting will occur almost entirely within the created gaps and the total area harvested per cutting cycle is likely to be 10 % or less of the stand area.

However, if the silvicultural prescription specifies that only a few openings will be created or group selection openings are being implemented together with a single-tree selection prescription (on the portions of the stand between openings), harvest regulation should be calculated by basal area control. In this case, the residual basal area of the stand between the gaps must be maintained at a higher level than is recommended in **Tables 6.1.4 to 6.1.7**, to compensate for the openings that will have a basal area of zero following cutting. Tree removal priorities remain the same - culls and near culls, trees with significant cull in the butt log, low grade trees not expected to attain sawlog quality, short-lived species or species with low-vigor (Miller et al. 1998).

Managers should consider using volume control to determine the amount of wood to be harvested when group selection openings in one cutting cycle will constitute more than 10 % of the stand area.

It is unlikely that an entire stand would be suited to group selection. Generally there will be portions (e.g., 10 to 90 %) that are left undisturbed, managed on a longer rotation, or treated with single-tree selection or some other silvicultural system.

Area Control

The total area of group openings should be calculated in the following way:

% of stand total area in group openings in each cutting cycle	=	% of stand to be managed by group selection	÷	rotation age (years to merchantable size) / cutting cycle (years between periodic harvests)

For example, assuming

- 80 % of the stand is to be managed by group selection
- the rotation age to merchantable size is 120 years
- the cutting cycle is 15 years, and
- there is no thinning between openings

then a maximum of 10 % (rounded to the nearest 1 %**),** of the total stand area should be in group openings during each periodic harvest.

Control of the amount of periodic harvest by area involves creating and maintaining age classes within the stand that result in the total area in group selection openings being approximately the same size for each periodic harvest.

The following calculations illustrate how the harvest should be regulated, and how the stand would develop after one rotation, given a 25 ha stand with the same rotation age, cutting cycle, and stand proportion in group openings as presented above:

- 20 % x 25 ha = 5 ha would be left uncut
- a maximum of **2.5** ha of the stand would be in group openings each cutting cycle (i.e., 10 % x **25** ha = **2.5** ha)
- after 8 successive periodic harvests (i.e., **8** x 15-year cutting cycle = **120** years later), the stand would be comprised of approximately **8 age classes comprising approximately 2.5 ha each: 15, 30, 45, 60, 75, 90, 105, 120**, plus an additional 5 ha that was left as uncut old growth. In reality, some of the trees in each age class patch might be older if regeneration was present at the time of cutting. **Also within each age class, patch numbers could range from as high as 5 patches of 0.5 ha to as many as 25 patches of 0.1ha, depending on the prescribed patch sizes and stand conditions**.

Basal area control

Prior to tree marking, the forest inventory should determine the area of the stand that is suited to group selection openings. This area should be incorporated in the single-tree selection prescription and generally should not exceed 10 % of the total stand area. A residual target basal area should be set based on the stand structure, quality and management objectives. The basal area between openings will need to be higher than this target to accommodate the total loss of basal area in the openings following haresting.

The higher residual basal area to be left between gaps should be calculated in the following way:

Target residual BA between groups (m^2/ha)	=	Target residual BA for the single-tree selection prescription (m^2/ha)	÷	% of the stand to be treated with single-tree selection prescription only (i.e., proportion not in group openings)

For example, assuming:

- 90 % of the stand is to be managed by single-tree selection
- the target residual BA for the single-tree selection prescription is 20 m^2/ha (for stems 10 cm in DBH and larger)

then the target residual basal area to be left between group openings should be 22 m^2/ha.

Tree-marking crews that are marking both single trees and creating some group openings in the same stand, must keep track of the number and size of the group openings they create and ensure they do not exceed the target total area to be treated by group selection (i.e., 10 % in this example).

<u>Volume control</u>

The total volume to be harvested must be determined by adding the sum of the volume of wood removed throughout the stand by single-tree selection thinning *plus* the volume of wood removed from the group selection openings. Furthermore, this total volume should not exceed the estimated volume of growth that can be expected during a cutting cycle, since sufficient residual stand basal area must be retained to provide a future sustained yield (Miller *et al.* 1995).

Regulating the amount of wood to be harvested by volume control requires good stand growth information that allows managers to be confident of the average annual growth rate of the stand. **Table 7.2.2** shows a considerable range in the annual volume growth among even-aged hardwood stands in Site Regions 6E and 7E. If accurate annual growth rate information for the stand is not known, conservative estimates of growth should be used to determine the volume to be harvested.

Using volume control, the amount to be harvested **at each cutting cylce** should be calculated in the following way:

Volume to be harvested (m^3**) per cutting cycle**.	=	Annual volume growth of the stand (m^3/ha)	x	Total stand size (ha)	x	Number of years in cutting cycle.

For example, assuming:

- a conservative annual growth estimate of 3 m^3/ha/yr in a typical upland tolerant hardwood stand in Site Region 6E
- a stand size of 20 ha, and
- a cutting cycle of 15 years

then the volume to be harvested by a combination of single-tree and group harvesting is 900 m^3 per cutting cycle. This is roughly equivalent to 204,300 bd.ft. or **4,134** bd. ft./acre.

Size of openings

The size of the group selection openings will vary according to:

- silvicultural objectives
- site conditions such as slope and aspect that can affect incident sunlight, and increased susceptibility to early spring frosts
- the autecology of tree species (i.e., its shade tolerance as a seedling and as a mature tree, recognizing that many species require shaded conditions to germinate and establish, but require more sunlight to survive and grow into the canopy)
- tree quality (i.e., clumps of overmature, decadent, or diseased trees that might be removed)
- height and canopy density of adjacent trees
- wildlife habitat and aesthetic considerations

However, in order to better mimic natural patterns of disturbance, group openings should not be of uniform size across the stand.

More specifically, opening size will depend on the light requirements of the target species and can range from approximately 0.02 ha to 0.20 ha (i.e., circular patches 16 in to 50 in in diameter or one to two times the canopy height (Leak and Filip 1977; Miller et al. 1995). **Table 6.1.9** converts the size of an opening to amount of light available for different canopy heights. The correct opening size is particularly important when managing mid-tolerant species, to avoid competition from less desirable intolerant species (Dale et al. 1995).

Larger gaps are critical to regenerate species with low shade tolerance (Runkle 1985). Group selection openings of at least 1.5 times the height of the adjacent, mature trees (i.e., circular patches 37 in in diameter or 0.1 ha) are required for successful regeneration of intolerant species such as black cherry and tulip tree and intermediate species such as northern red oak, white oak, basswood, and white ash (Miller et al. 1998).

In the Porcupine Mountains of upper Michigan, Dahir and Lorimer (1996) found that mid-tolerant species such as yellow birch and green ash only had a competitive advantage over sugar maple and hemlock in gaps greater than 80 m2 (i.e., approx. 0.01 ha). In general, intolerant species such as poplar and white birch require a minimum gap size of 1000 m2 (0.1 ha) to regenerate successfully (Shugart 1984 in Anderson and Rice 1993). Although larger openings tend to support more intolerant and fewer tolerant species, competition from shrubs and herbaceous species can be intense. Refer to **Table 6.1.10** for recommendations concerning opening size required for regeneration of several tree species. Few studies have investigated size of openings for group selection in Ontario, so results from other areas should be used with caution. Follow-up monitoring to determine whether the desired species are regenerating is critical.

The rate at which small openings close over, due to lateral growth of surrounding canopy trees, can also affect gap size. For example, with an average gap diameter of 0.5 times canopy height, and a lateral crown expansion of 15 cm/year, Hibbs (1982) estimated that yellow birch would have to maintain a height growth rate of 45 cm/year to reach the canopy prior to its closure and that tree reproduction was unsuccessful in openings with diameters of less than about 0.5 times canopy height, mainly because small openings closed too quickly. However if cutting cycles are planned for intervals of less than 20 years, these edge effects could be modified by the normal single-tree marking process (Anderson and Rice 1993).

Table 6.1.9. Area of circular group selection gaps (ha)[1] and average percentage of full sunlight (% FS), with gap diameter expressed as proportion of border tree height (adapted from Fischer 1977).

Group opening diameter, shown as a proportion of border tree heights (m)	Border tree height (m)				Range in % FS	
	15	20	25	30	North aspect	South aspect
0.5	0.004 [2]	0.008 [2]	0.01 [2]	0.02	0 – 4	4 – 8
1.0	0.02	0.03	0.05	0.07	12 - 25	25 – 35
2.0	0.07	0.13	0.20	0.28	32 – 52	52 – 58
4.0	0.28	0.50	0.79	1.13	50 - 75	75 - 79
8.0	1.13	2.01	3.14	4.52	60 – 85	85 – 90

[1]Circular gap area (ha)= $((H/2)^2 \times (\pi))/(10{,}000 m^2/ha)$, where H = border tree height (m), and $\pi = 3.14159$.
[2]Roughly equivalent to single-tree gaps, based on average tree crown diameters, developed from Cole 1991; Lorimer 1983, and Marquis 1967. All other border tree height-gap size combinations are larger than single-tree gaps.

Table 6.1.10: Recommended group selection gap sizes for tree species of different shade tolerance classes.

Shade tolerance	Species	% full sun-light for best seedling growth after establish-ment	Diameter of circular group opening		Location	Reference
			Proportion of average stand height	Area (ha)		
Very intolerant	poplars			> 0.1		Shugart 1984
	white birch			> 0.1		Shugart 1984
	white birch	45			central Ontario	Logan 1965
	white birch			0.04-0.3	New Hampshire	Marquis 1965
	very intolerant[1,2]			0.4-0.8	northeast US	Leak and Gottsacker 1985
Intolerant	black ash	25-45 yr 1 45-50 yr 2+			Lake States	Erdmann *et al.* 1987
	black cherry		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	black cherry			> 0.08	northeast US	Nyland 1987
	silver maple	45			central Ontario	Logan 1965
	hickory spp.[3]		0.75–2.0		southern Illinois	Minckler *et al.* 1973
	tulip tree		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	tulip tree[3]		1.5-2.0		southern Illinois	Minckler *et al.* 1973
	intolerant[4]			> 0.2, 0.4 recommended	West Virginia	Trimble 1973
Mid-tolerant	American basswood		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	American basswood	25-45			central Ontario	Logan 1966, cited *in* Tubbs 1977a
	green ash[5]			> 0.008	northern Michigan	Dahir and Lorimer 1996
	red oak	> 1.0 – 1.4		> 0.015	southwest Wisconsin	Lorimer 1983
	red oak			> 0.04	Michigan	Rudolph and Lemmien 1976, cited *in* Lorimer 1983
	red oak		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	red oak		> 2.0		Massachusetts	Hibbs 1982
	red oak		1.0 – 2.0		southern Illinois	Minckler 1989
	red oak			> 0.2	central Ontario	Anderson *et al.* 1990
	black and red oak[3]		1.5-2.0		southern Illinois	Minckler *et al.* 1973
	black and red oak[6]		0.75-2.0		southern Illinois	Minckler *et al.* 1973
	white ash		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	white ash	25-45 yr 1 45-50 yr 2+			Lake States	Erdmann *et al.* 1987
	white ash	25-45			central Ontario	Logan 1973
	white ash			> 0.08	northeast US	Nyland 1987
	white oak		> 1.5	> 0.17	West Virginia	Miller *et al.* 1998
	white oak			0.04	Michigan	Rudolph and Lemmien 1976, cited *in* Lorimer 1983
	white oak		0.75-2.0		southern Illinois	Minckler *et al.* 1973

[1] Very intolerant species: white birch, poplars; mid-tolerant species: yellow birch, white ash, red maple; tolerant species: American beech, sugar maple, hemlock, red spruce;
[2] Study results: approximately 50 % dominance by very intolerant and mid-tolerant species and 50 % dominance by tolerant species
[3] Coves and north slopes
[4] Intolerant species: scarlet oak, butternut, hickories, tulip tree, sassafras, black cherry
[5] Successful gap regeneration in unmanaged old-growth northern hardwood stands
[6] South slopes

Table 6.1.10: *continued*

Shade tolerance	Species	% full sunlight for best seedling growth after establishment	Diameter of circular group opening		Location	Reference
			Proportion of average stand height	Area (ha)		
Mid-tolerant *continued*	yellow birch			0.1-0.2	central Ontario	Anderson *et al.* 1990
	yellow birch	25-45			central Ontario	Logan 1965
	yellow birch			0.04-0.08	Lake States	Tubbs 1977a
	yellow birch[6]			> 0.008	northern Michigan	Dahir and Lorimer 1996
	yellow birch			>> 0.04-0.08	Lake States	Eyre and Zillgitt 1953
	yellow birch			0.04-0.08	Lake States	Arbogast 1957
	yellow birch			0.08-0.4 (avg. = 0.2)	New Hampshire	Leak and Filip 1977
	yellow birch	< 50			Lake States	Godman and Krefting 1960
	yellow birch		> 0.5-1.0		Massachusetts	Hibbs 1982
	yellow birch			0.04-0.3	New Hampshire	Marquis 1965
	mid-tolerant[7]			> 0.2-0.4	West Virginia	Trimble 1973
	mid-tolerant[8]			0.04-0.3	northeast US	Leak *et al.* 1969
	mid-tolerant[1,2]			0.4-0.8	northeast US	Leak and Gottsacker 1985
	mid-tolerant[1,9]			0.2-0.3	northeast US	Leak and Gottsacker 1985
Tolerant	American beech	13-45	0.5		central Ontario	Logan 1973
	hemlock				central Ontario	Anderson 1990
	hemlock	25-45	> 0.5		central Ontario	Logan 1973
	hemlock				Massachusetts	Hibbs 1982
	sugar maple	13-45			central Ontario	Logan 1965
	sugar maple				Massachusetts	Hibbs 1982
	sugar maple[10]			0.04–0.08	Lake States	Eyre and Zillgitt 1953
	tolerants		< 0.5		northeast US	Dale *et al*. 1995 Minckler 1989
	tolerant[1,11]			< 0.01	northeast US	Leak and Gottsacker 1985

[1] Very intolerant species: white birch, poplars; mid-tolerant species: yellow birch, white ash, red maple; tolerant species: American beech, sugar maple, hemlock, red spruce;
[2] Study results: approximately 50 % dominance by very intolerant and mid-tolerant species and 50 % dominance by tolerant species
[6] South slopes
[7] Mid-tolerant species: cucumber tree, white ash, basswood, black gum, yellow birch, white oak, red oak, black oak, slippery elm, serviceberry
[8] Mid-tolerant species: yellow birch, red maple, white ash; very intolerant species: poplars, white birch; large gap sizes favor very intolerant species
[9] Study results: approximately 33 % dominance by mid–tolerant and very intolerant species, and 67 % dominance by tolerant species
[10] Sugar maple dominated all regeneration, but small component of yellow birch present
[11] Study results: approximately 90 % dominance by tolerant species

Number of openings at each periodic harvest

The number of openings is not as important as the total area of a stand that is maintained in openings during any one cutting cycle. As a general rule, fewer openings are preferred to many, at least until the forest manager can clearly demonstrate successful regeneration of desired species in these openings, to polewood size; adequate site recovery from silvicultural intervention; and minimal disruption to wildlife habitat.

In the central Appalachians, one formula used to determine the number of group selection openings needed at each periodic harvest is defined by:

$$N = (CC/H) * (A/G)$$

Where:
N= number of group selection openings needed
CC= cutting cycle
H= harvest age of mature trees in years
A= stand area in hectares
G= average group opening size in hectares (Miller *et al*. 1998).

Shape of openings

The shape of group openings can vary but rounder or more square-shaped gaps may provide better sunlight conditions for regeneration than longer, narrower gaps that result in increased shading in the opening (Miller *et al.* 1998) and chance of windthrow. If landowners and managers wish to minimize the amount of edge habitat, circular or square openings should be preferred to rectangular openings.

Location of openings

Group openings are located in tolerant hardwood stands where site and stand conditions suggest potential opportunities for the regeneration of mid-tolerant species. For example, a suitable area might be one located near a suitable seed source, with appropriate soil and microclimatic conditions, and a patch of large, lower quality trees that can be cut and removed with minimal impact on the site.

Consideration should also be given to local topography variations. For example, group openings on mid- to upper slopes should be designed primarily to take advantage of advanced red oak, white pine, or hickory regeneration. Many other species may be present as advanced regeneration on upper slopes, but have limited long-term potential (e.g., white ash). Group openings on mid- to lower slope sites will create suitable light conditions for a wide variety of species, but slow-growing species like white pine or red oak must be large enough to compete with faster-growing species that may also be present on these sites. When present as advanced regeneration, faster-growing species like basswood, white ash, black cherry, yellow birch, or butternut will respond well to the light conditions created by group selection, and are all well-suited to the soil moisture conditions that occur on mid- to lower slopes. Advanced sugar maple regeneration will flourish on most site conditions.

The potential for creating frost pockets in group openings due to variation in local topography should also be considered. **Table 6.1.11** provides a relative ranking of the spring frost susceptibility of many mid-tolerant species that might be considered for management by group selection silviculture. Although this table was based on information from the Appalachian mountains of North Carolina, almost all of the species mentioned occur in southern Ontario. If regeneration of a particularly frost sensitive species (e.g., tulip tree, black walnut) is desired, managers should carefully consider whether the proposed location of the group opening will be exposed to frost.

Table 6.1.11: Susceptibility of tree species to damage to newly formed leaves and shoots by late frosts in northern and east-central West Virginia (adapted from Trimble 1973, using information from Tryon and True 1964).

Highly susceptible [1]	Moderately susceptible	Less susceptible	Least susceptible
sassafras		smooth alder	slippery elm [2]
American sycamore	white ash [3]	serviceberry	willow [2]
black locust	American chestnut	witch-hazel	flowering dogwood [2]
American beech	white oak	striped maple	hawthorn
cucumber tree	northern red oak	red maple	American basswood
tulip tree			sugar maple
hickory species			black cherry
black walnut	yellow birch [3]		
butternut			

[1] The most susceptible species are at the top, and the least susceptible are at the bottom, within each susceptibility class.
[2] Based on few observations.
[3] Considerable variation in degree of damage.

Group openings should also be located using a "worst first" approach, in places where potential growth or value returns are low compared to other parts of the stand, such as where groups of mature, low quality, or undesirable trees show relatively poor growth or economic potential (Miller *et al.* 1999; Trimble *et al.* 1974). Finally, group openings should be located with an objective of eventually improving the productivity of the residual stand. Creating group openings in the middle of an old stand, or on windward edges, can make the stand more susceptible to windthrow.

Thinning between openings

Several factors influence the decision to thin between group openings, including: overall stand management objectives, stand and tree quality, tree vigor, potential increase in timber value of trees that might result from thinning operations, cost of thinning operations, and risks (e.g., damage to trees, site, and/or significant wildlife habitat, increase in competition from undesirable species). Generally, some thinning for stand improvement (e.g., to increase growth, improve quality of the residual stand) is recommended if it is productive, affordable, and can be conducted with little detrimental impact on desirable regeneration, the site, and important wildlife habitats.

To avoid over-cutting a stand, an estimate of the volume of this thinning must be made during the stand inventory and included in the total harvest volume when calculating the maximum allowable cut (Miller *et al*. 1995). In order to maintain the residual basal area target for the entire stand, the creation of group openings requires that higher stocking be retained in between these openings. Also stands that require a large amount of improvement cutting (e.g., high-graded stands) should be thinned first, with the creation of few or no group openings until the next cutting cycle (Miller *et al.* 1995).

Crop-tree selection

Residual trees that will be harvested in the future should be selected not only for their superior market value (e.g., black cherry, northern red oak, white ash, sugar maple), but also for their potential log quality, growth, longevity, and risk (Miller *et al.* 1998). More specifically, these trees should be vigorous, dominant or codominant, and free of signs of stress (e.g., no epicormic branches on the bottom 33 ft (10 m) of the bole (Miller *et al*. 1995)). Trees in subordinate crown classes tend to develop more epicormic branches, leading to a reduction in timber quality. Also trees should not show signs of risk (e.g., low fork, poor rooting) because they will be retained for many years after the initial cut.

Treatment of advanced regeneration

The group selection system is more likely to be successful if the desired advanced regeneration is established before the creation of group openings, especially for species such as red oak that are difficult to regenerate. However, non-target species (e.g., sugar maple) with diameters of at least 2 cm DBH that have been suppressed or will not contribute to long-term stand level objectives will interfere with the development of desired mid-tolerant regeneration, and should be removed from group selection openings (Miller *et al.* 1995). In most cases, the regeneration that will develop best in group openings is of those species present as advanced regeneration before openings are created.

Timing of operations

Table 8.3.3 provides a list of the advantages and disadvantages of harvesting during different seasons, and should be consulted before scheduling harvesting operations. Summer logging will disrupt nesting and breeding wildlife and decrease reproductive success of forest interior birds if the stand is being used by these wildlife species.

Specific wildlife habitat concerns

The occurrence of any specific wildlife habitats listed in **Table 4.4.1** should be noted in the silvicultural prescription and the recommended actions suggested in this table should be followed.

Follow-up requirements

On some sites, follow-up tending to ensure the desired species have a competitive advantage may be critical. If managers cannot commit to follow-up tending (for a period of approximately five years or until the desired species are well established in the openings), group selection is not recommended, especially when creating larger openings (e.g., 1.5 to 2 times tree height) since openings of this size have not been tested in southern Ontario forest conditions. On some sites, the group openings may also require maintenance to control invasive exotic species (**Section 8.1** recommends methods of control for the most serious species found in the forests of southern Ontario).

To determine whether any follow-up treatments are required, managers will need to monitor group openings on an annual basis until regeneration is well-established. Otherwise, group selection will not achieve its full potential on most sites, and the resulting species composition in the openings will likely be disappointing.

Suggested modifications for unique stand conditions

Management of tolerant hardwood stands to provide some larger canopy openings

Silvicultural objective

- to use a modified group selection system to simulate natural canopy gap-phase disturbance events in order to develop or maintain some patches of mid-tolerant species within a stand being managed by single-tree selection

The purpose of creating a few larger canopy openings in tolerant hardwood stands being managed by single-tree selection is to retain or restore a component of mid-tolerant species for wildlife habitat values, as well as to produce some high quality sawlog material. In older-growth deciduous and mixed forests that have been studied, gaps in the canopy occupied 5 - 24 % and 3 - 5 % of stand area, respectively (Keddy 1994), so this modification attempts to simulate this frequency of canopy openings.

Stand description

Selected stands should contain mature, seed-producing mid-tolerant tree species.

Silvicultural prescription

Management should be designed to closely mimic gap-phase mortality patterns and to minimize logging disturbance because studies of old-growth forests suggest that major stand-replacing fires or windstorms were relatively rare on upland loamy sites. Instead, small gaps were created by the fall of one to several large trees, resulting in the creation of a forest of shade-tolerant species with canopy openings of varying sizes from 0.004 to 0.04 ha (0.01 to 0.1 acre) and a range of age classes.

This objective is achieved by:

- Applying area control to determine the number and size of group openings and applying basal area control to apply single-tree selection thinning between openings. Basal area control is familiar to tree-markers, and area control of group openings is simple to apply.
- Since the objective is to maintain a component of mid-tolerant species within a tolerant hardwood stand, than the percentage of the stand in group openings should reflect the percentage of mid-tolerant species composition desired. For example, if a 25 % mid-tolerant species composition is desirable than group selection is applied to 25 % of the stand. If the

cutting cycle and rotation are 20 years and 100 years, respectively, then applying the formula for ‘Area control’ regulation of group openings (below) suggests that group selection openings should be made on 5 % of the stand’s total area each cutting cycle.

% of stand total area in group openings in each cutting cycle	=	% of stand to be managed by group selection	÷	$\frac{\text{rotation age}}{\text{cutting cycle}}$

- Since single-tree selection is being applied to the remainder of the stand, thinning between openings should occur each cutting cycle. Thinning between openings should be done to a target residual basal area (as determined from one of the ideal basal area distributions by diameter-class given in **Tables 6.1.4** to **Table 6.1.7**). In order to avoid over-harvesting, the group selection areas should be well delineated, for example by applying tree-marking paint to indicate future openings where no trees will be harvested during the current cutting cycle. Additionally, the basal area target for the single-tree selection application should be increased as discussed for ‘Basal area control’ in the ‘Harvest regulation’ section.
- The number of group openings will be determined from the size of openings which will vary depending on the mid-tolerant or intolerant species desired as regeneration in the group openings (see **Table 6.1.10**).
- The shape of openings should vary by aspect and orientation (see **Table 6.1.9**).

Management of mid-tolerant regeneration in areas with high deer density

Deer browsing can have a devastating affect on tree regeneration. The risk of regeneration failure due to browsing is greatest when the local deer population is relatively high and harvests promoting regeneration occur in areas where the availability of food for this mammal is relatively low. Deer tend to concentrate their feeding in recently harvested stands where new seedlings and sprouts are abundant. Harvests should be planned so that deer browsing pressure on regeneration is dispersed over a large area of the landscape. Additional methods include fencing to exclude deer and the use of tree shelters in group openings.

Uniform shelterwood system

Introduction

The uniform shelterwood system seeks to manipulate the main canopy to promote an adequate seed supply and desirable overhead shade and shelter to stimulate the germination and rapid growth of desirable species (**Section 3.1**).

Drawbacks of using this silvicultural system in tolerant hardwood forests include:

- poor markets for thinnings due to poor initial stand quality
- harvest operations may have to be conducted in winter to minimize damage to advance regeneration. In southern Ontario, climatic conditions frequently result in too little snow, short periods of unseasonably warm temperatures during the winter months, and/or saturated soils, all of which prohibit winter harvest.

In tolerant hardwood stands, the first cut is a regeneration cut. The second cut can be a removal cut, if advanced regeneration has been established, but it may also be a regeneration cut used to further open a stand where abundant seedlings have become established. In this latter case, the overstory removal cut would proceed when the advanced regeneration was established. The use of this system for regenerating upland oaks is discussed in **Section 6.2**.

Silvicultural prescriptions for applying the uniform shelterwood system in tolerant hardwood stands should include specific instructions concerning:

- silvicultural objective(s) for the forest stand
- specific wildlife habitat concerns
- the regeneration (seed) cut
- seed-tree selection
- seedbed preparation
- control of competing vegetation, and
- the removal cuts.

Each of these aspects is discussed in the following

Silvicultural objective(s)

In the tolerant hardwood forests of southern Ontario, the uniform shelterwood system has been used:

- to convert to or maintain even-aged stands
- to replace a decadent, unhealthy, poor quality, or otherwise unproductive overstory (i.e., the stand quality is not sufficient for selection system management)
- to encourage regeneration of small or light-seeded species (e.g., yellow birch, paper birch, and hemlock)

- to regenerate mid-tolerant species that require a seed source, partial sunlight and shelter to become established and full sunlight to develop (e.g., red oak, white pine, but not basswood or white ash)

Specific wildlife habitat concerns

Summer logging will disrupt nesting and breeding wildlife and decrease reproductive success of forest interior birds if the stand is being used by these wildlife species. As well, the final removal cut removes most of the high canopy.

Regeneration (seed) cut

The regeneration seed cut promotes suitable sunlight and shade conditions to encourage desired regeneration, but maintains enough shade to both discourage establishment of herbaceous and shrub competition and prevent desiccation of the soil surface. The retained trees should as much as possible be of the desired crop species, but cover should be uniform, and may therefore require leaving some less desirable species or smaller trees. Ideally, dominant and codominant trees of good form, vigor, and uniform distribution throughout the stand are identified for retention.

Retention of an overstory with 80 % crown closure will encourage regeneration of sugar maple, beech, and other tolerant species, while retention of an overstory with 30-50 % crown closure (or perhaps somewhat higher on wet sites) will encourage mid-tolerant species, especially yellow birch (Perkey *et al.* 1993). Hannah (1988) states that many species will regenerate with about 60 % crown closure. **Table 6.1.12** presents recommended crown cover percentage targets for selected species.

Table 6.1.12: Recommended crown cover percentage targets for regeneration cut, by species.

Species	Recommended crown cover % targets for regeneration cut
Basswood	40 - 50 %
Black cherry	30 – 40 % (Hornbeck and Leak 1992)
Red oak	60 - 70 % (Dey and Parker 1996)
Tulip tree	30 – 40 % (Hornbeck and Leak 1992)
White pine	40 - 50 % (OMNR 1998*b*)
Yellow birch	40 - 50 % (OMNR 1998*a*)

Seed-tree selection

Cankered trees should be cut before or during the first shelterwood cut to remove potential sources of infection. The guidelines for selecting quality crop trees that were discussed in **Section 5.3** should be followed. Recall that one reason for choosing the uniform shelterwood system to manage a stand dominated by sugar maple may have been the presence of fewer than 9 m^2/ha BA in AGS quality trees. The regeneration cut should retain these few best-quality trees to encourage seed production from them.

Tree marking

Tree marking for shelterwood cuts should be based on leaving a target percentage crown cover. There are two ways of implementing this by tree marking. Researchers from the northeastern United States advocates marking to a residual crown area that provides the percentage crown cover rather than a pre-determined basal area (**Table 6.1.12**). This is because basal area is not a good indicator of crown cover from species-to-species or in stands with various diameters (Godman 1988). See **Box 6.1.1**: A Worksheet for Shelterwood Marking by Crown Area**,** for specific tree-marking instructions for this approach.

However, subsequently marking by eye after calculating crown area in practice plots, is difficult to implement in the field. Generally in southcentral Ontario, uniform shelterwood marking is implemented by having tree-markers adhere to crown spacing guidelines. Where stands are fairly uniform in both species composition and diameter, an average crown spacing can be determined from the practice plots and used as a guideline for marking the regeneration cut in the remainder of the stand.

Seedbed preparation

Seedbed preparation (e.g., scarification) may be used following the regeneration cut to promote regeneration of light-seeded species. If advanced regeneration already exists, harvest in winter in deep snow and/or use a forwarder without ground skidding to minimize logging damage. Do not scarify.

Small- or light-seeded species such as yellow birch and basswood prefer a lightly disturbed forest floor in which litter is removed and the organic layer and upper mineral soil horizons are mixed. These seedbeds retain moisture better and increase surface soil temperatures for germination of light-seeded species. For species that prefer a disturbed leaf litter seedbed, normal logging operations should provide abundant suitable regeneration sites. Seedbed preparation is not usually required for most tolerant or mid-tolerant species with moderately heavy or heavy seeds (e.g., sugar maple, beech, white ash, red oak, and black cherry). Refer to **Appendix B** for detailed information on the seedbed requirements of the tree species for which regeneration is desired. Seedbed requirements for the more commonly occurring tolerant hardwood species are provided in **Table 6.1.1**.

Harvest operations may result in crude cultivation of the forest floor, removal of leaf litter and compaction**,** but usually such disturbance is limited to 10 to 15 % of the stand area (OMNR 1998*a*). A mixed mineral soil/humus seedbed can be obtained by planned mechanical site preparation treatment. For example, a small bulldozer equipped with toothed blades or root/rock rakes can be used to displace the litter layer on the forest floor and expose the moist decomposing layer of duff on approximately 60 % of the stand area. Or drag-type scarifiers such as 10-kg-link anchor chains equipped with gouging pins can be used to break up litter, rip out established competing species, and mix the humus and mineral soil (OMNR 1998*a*).

Controlling competing vegetation

Hannah (1988) stresses the importance of controlling competing vegetation in the understory until the regeneration of desired tree species is well established. Manual cutting, burning, or herbicides can be used to control undesirable understory vegetation. Each of these treatments has advantages and disadvantages that must be considered in conjunction with other factors such as the location of the stand in the surrounding landscape and landowner objectives. See **Section 8.1** for specific details.

Removal cut(s)

The key to success with this method is to ensure there is adequate advanced regeneration prior to removal of the overstory. Godman (1992) stresses the importance of establishing advanced hardwood regeneration before overstory removal and believes that seedlings should be 60-120 cm high because by then, their root systems have penetrated mineral soil. According to Perkey *et al.* (1993), well-established regeneration for beech, sugar maple, and hemlock should be 91 to 122 cm high and at least 61 cm tall for white birch.

Most of the overstory should be removed after seedlings are established and have reached the target heights shown in **Table 6.1.13**, usually within five to 10 years of the original regeneration cut, leaving some supercanopy trees, in stands where they exist, to provide important wildlife habitat. Care must be taken because overstory removals that occur when saplings are 2.5 cm DBH or larger, can cause excessive uprooting and breakage.

In practice, managers of tolerant hardwood stands in southern Ontario have rarely implemented the removal cut. In most cases, the regeneration cut is used to remove the poor quality stems in a thinning from below, with the goal of eventually managing the resulting better quality stand as uneven-aged by single-tree selection (E. Boysen, OMNR, personal communication, 2000).

Table 6.1.13: Minimum acceptable heights for advanced regeneration, by species (adapted from Kelty 1988).

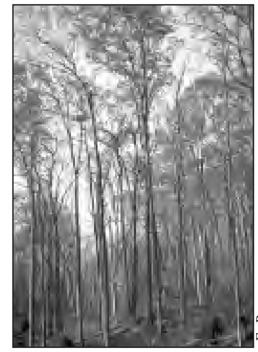
Species	Minimum acceptable height (cm) of advanced regeneration
American beech	61 *
Basswood	61
Black cherry	15
Eastern hemlock	61 *
Red maple	61
Red oak	137
Sugar maple	61 *
White ash	61
White oak	137

* Ideally should be sapling size (2.54 to 9.8 cm DBH) to reach overstory in new stand.

Box 6.1.1: A worksheet for calibrating stand density reductions in hardwood shelterwood marking (from Godman 1992).

1. Lay out a 400 m^2 (1/10 acre) circular plot with a radius of 11.28 m (37.24 ft.) in the stand to be marked.
2. Select the appropriate % Crown Cover for the cut-type and species desired for regeneration from **Table 6.1.13**, and calculate the residual crown cover needed.
3. Residual crown cover needed = % Crown Cover/100 x 400m^2 = _______ m^2
4. Tally the diameter and species of residual trees, and crown area in m^2 (see Step 5).
5. Crown area is calculated by estimating the crown radius in meters and applying the formula for the area of a circle (i.e., Crown Area (m^2) = Π * crown radius^2 (m).
6. Sum total crown areas in m^2 as they are tallied.
7. Begin simulated marking by picking crop trees for retention. Identify these trees with flagging tape.
8. Ensure that residual trees are: well distributed over the plot, of the desired species, and exhibit good crop-tree qualities (e.g., no defects, good vigor, straight stems).
9. Add the crown areas of the residual trees as they are chosen.
10. Stop marking when the calculated residual crown area is reached.
11. All trees (2 cm DBH and larger) not marked for retention would be removed.
12. Use the 400 m^2 circular plot as a standard for marking the remainder of the stand by eye.
13. From time to time lay out additional plots in other parts of the stand for comparison.

6.2 UPLAND OAKS



E. Boysen

by Ken Elliott, Silvia Strobl and David Bland

Introduction

Upland oak forests, as defined in this guide, are comprised of at least 50 % oak and hickory species. A variety of other tree species such as poplar, white pine, black cherry, white ash, sugar maple, red maple, ironwood, basswood, beech, and eastern red cedar may also occur in these forests but normally do not form a dominant component. Forest types dominated by black oak are found mainly in Site Region 7E. Also upland forests in this site region may contain Carolinian species such as sassafras, chinquapin oak, and tulip tree that are more characteristic of the deciduous forests of some parts of the northern United States.

Upland oak forest canopies are usually more open than those of the tolerant hardwood forests, with canopy closure ranging from 60 to 75 %. Soils are often shallow and droughty. Drainage varies but often ranges from rapid (DR 2) to moderately well-drained (DR 4). Site moisture regimes commonly range from dry (MR 0) to fresh (MR 1,2,3).

Stands with a composition of slightly less than 50 % oak and/or hickory species can still be managed under the proposed silvicultural systems described in this section, but lower species composition percentages (e.g., less than 30 % oak species) can be managed as individual trees dictate (i.e., when oak is encountered in sufficient quantity, it can be managed).

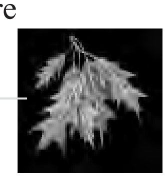
Forests dominated by oak species are most common in southwestern Ontario. The ELC for southern Ontario describes four Ecosite (Lee *et al.* 1998) that correspond to upland oak forests in which oak species comprise the dominant component. These ecosites are briefly described below.

Dry-fresh oak deciduous forest ecosite (FOD1)

This ecosite is typically found on sands and coarse loams or on sites with shallow soils (e.g., less than 30 cm deep). Gley is not found in these soils. Mottles, if they occur, are located below 60 cm. Frequently this forest ecosite is found on upper to mid-slope and tableland topographic positions.

In general, the vegetation of this ecosite is adapted to tolerate well-drained, droughty soils; direct sunlight; and periodic disturbance (e.g., fire). Oak species exhibit several such adaptations including the ability to develop deep root systems and resprout from suckers, and a relatively thick, fire-resistant bark.

The ELC for southern Ontario describes four forest types for this ecosite. One of them, the dry-fresh black oak deciduous forest type, is dominated by black oak, growing in association with eastern red cedar, poplar species, and black cherry, and is considered rare in southern Ontario. It is most common in Site Region 7E. Another, the dry-fresh mixed oak deciduous forest type, is also considered rare in southern Ontario. It is characterized by having more than two codominant oak species (e.g., red, white, black, bur, or chinquapin oak), and is also more



common in Site Region 7E, but also occurs on the Frontenac Axis in southeastern Ontario, and sporadically on dry ridges throughout Site Region 6E. The two other forest types, the dry-fresh red oak deciduous forest types and the dry-fresh white oak deciduous forest type are dominated by red and white oak respectively, and are common in both site regions.

Dominant Trees	red oak, white oak, or black oak, either as single or mixed-species stands
Less Common Associates	red maple, white pine, and black cherry; sugar maple is an uncommon associate
Common Shrubs	wintergreen, low sweet blueberry
Common Herbs and Ferns	bracken fern, starflower
Soil Moisture Regime	dry (MR 0) to fresh (MR 1,2)
Soil Drainage	rapid (DR 2) to well-drained (DR 3)
Equivalent Ecosite in Central Ontario	ES14 but no black oak in Site Region 5E, white oak uncommon; occasionally occurs on moist soils (Chambers *et al.* 1997)

Dry-fresh oak-maple-hickory deciduous forest ecosite (FOD2)

This ecosite is typically found on sands and coarse loams having some silt and clay particles, as well as fine loams and clays. It appears to represent a transition from sites subject to periodic droughty conditions to sites with more available soil moisture. Like the preceding ecosite, gley is absent and mottles are found below a depth of 60 cm. Canopy closure tends to be higher than for the preceding ecosite. It is also often found on upper to mid-slope or tableland topographic positions.

Disturbance may occur infrequently on this ecosite. This factor, together with increased soil moisture availability, allows mid-tolerant hardwoods such as red maple, shagbark hickory, and bitternut hickory to become associated with the more intolerant oak species. If disturbance such as fire is suppressed, a shift in dominance to more shade-tolerant hardwoods is quite possible.

The ELC for southern Ontario describes four forest types for this ecosite. The dry-fresh red oak and dry-fresh oak-sugar maple deciduous forest types are common in both Site Regions 6E and 7E. The dry-fresh red oak-red maple deciduous forest type is common in Site Region 7E but only occurs sporadically on the Canadian Shield in Site Region 6E. The dry-fresh oak-hickory forest type is common on the Napanee limestone plain, but occurs sporadically elsewhere in southern Ontario. The dry-fresh hickory forest type is considered rare in southern Ontario.

Dominant Trees	red oak, and to a lesser extent, white oak, dominate or share dominance with other deciduous trees, commonly red maple, shagbark hickory, and bitternut hickory
Less Common Associates	sugar maple, white ash, beech, basswood, ironwood, and black cherry; sugar maple comprises less than 25 % of canopy cover
Common Herbs and Ferns	trilliums, hepaticas, bellwort, Jack-in-the-pulpit, zigzag goldenrod
Soil Moisture Regime	primarily fresh (MR 1,2,3) but may also be moderately dry (MR 0)
Soil Drainage	well-drained (DR 3) to moderately well-drained (DR 4)

Dry oak-pine mixed forest ecosite (FOM1)

This ecosite is comprised of mixed forest (i.e., conifer and deciduous) growing on dry upland sites. Soils are usually rapidly drained sands and loams. The canopy is typically open in nature.

The ELC describes two forest types for this ecosite. The dry pitch pine-oak mixed forest type only occurs in the Thousand Islands region on the Frontenac Axis. Pitch pine is considered to be a provincially rare species, and often grows on south-facing slopes, with red oak, white oak, white pine, and eastern red cedar. The dry chinquapin oak-pine mixed forest type is found sporadically throughout Site Region 7E, usually growing on shallow, coarser soils (e.g., sands). Common associates of this forest type include red oak, chinquapin oak, white oak, and white pine. Both these forest types benefit from disturbance such as fire that controls competition and encourages regeneration of the oaks and pines.

Dominant Trees	white oak, red oak, chinquapin oak, pitch pine, white pine in variable mixtures
Common Shrubs	low sweet blueberry, buffalo-berry, and common juniper
Common Herbs and Ferns	bracken fern
Soil Moisture Regime	dry (MR 0) to fresh (MR 1).
Soil Drainage	rapid (DR 2) to well-drained (DR 3)

Dry-fresh white pine-maple-oak mixed forest ecosite (FOM2)

The vegetation on this ecosite is also mixed conifer-deciduous on upland sites. It is found on both shallow and deep sands, loams, and clays.

The ELC describes one forest type that might correspond to upland oak forests. The dry-fresh white pine-oak mixed forest type is commonly found on the Frontenac Axis and occurs sporadically throughout Site Region 6E. It is rare in Site Region 7E but may have been more prevalent prior to logging (Lee *et al.* 1998). The most common dominant species are red oak, white oak, and white pine. Common associates include ironwood and red maple. Disturbances such as fire control competition and allow the pine and oaks to dominate.

Dominant Trees	white pine with sugar maple, red oak and to a lesser extent, white oak; dominant species varies
Less Common Associates	red maple, basswood, white ash and ironwood
Common Shrubs	serviceberry, wintergreen, downy arrowwood, low sweet blueberry, partridgeberry
Common Herbs and Ferns	bracken fern, gaywings, bristle-leaved sedge, white trillium and rough-leaved (mountain) rice grass
Soil Moisture Regime	dry (MR 0) to fresh (MR 1,2,3)
Soil Drainage	rapid (DR 1) to moderately well-drained (DR 4)

Carolinian species associations

Upland oak forests found in Site Region 7E (i.e., Carolinian Life Zone or Deciduous Forest Region) often include tree species found only in southwestern Ontario. These species include American chestnut, dwarf chinquapin oak, Hills oak, pignut hickory, and sassafras. If these species exist in the stand being considered for management, contact the OMNR District Ecologist to determine their degree of rarity within the local area and the greater region. The habitat of species considered to be locally or regionally rare or in serious decline should be protected. Endangered species, such as the cucumber magnolia, and their habitats, are protected by the Endangered Species Act.

Changes since the presettlement era

Many oak forests may have originated with human fires (Foster *et al.* 1992). In the northern conifer and hardwood forests of New England and the Lake States region, red oak increased dramatically following early logging and the subsequent fires set by settlers to clear land. Also early rail transport probably started many severe fires (from hot coals). Repeated burning may have contributed to soil sterilization in some areas. In eastern Ontario, studies at the turn of the century demonstrated that the diversity and density of trees was lowest in areas that were subjected to greater numbers of burns (Keddy 1993). But the frequency of red and white oak typically increased with repeated burning.

Studies of dendro-ecology and successional dynamics of several old-growth forests indicate that prior to European settlement, oak species grew and regenerated in uneven-aged conditions. Oak species were present in relatively low numbers in the overstory of the presettlement forest, but may have been pervasive in the understory of former pine forests (Abrams 1996). The expansion of oaks following large-scale fire disturbances was also helped by the widespread dispersal of acorns by birds and small mammals. Oak species also benefited from the elimination of overstory American chestnut trees as a result of the chestnut blight fungus in the early 1900s.

Throughout the northern tolerant hardwood forest, oaks exhibited continuous recruitment into the canopy during the 17th, 18th and 19th centuries, but this stopped in the early 20th century. Since that time, more shade-tolerant, late-successional species have dominated understory and canopy recruitment, coinciding with the period of fire exclusion throughout most of northeastern North America. Harvesting of oak forests that have understories dominated by later successional species often accelerates the oak replacement process (Abrams 1996).

A more recent and severe deterrent to oak seedling longevity and height growth that was probably not a major factor in presettlement forests is the browsing of oak seedlings by deer. In the eastern United States and much of southern Ontario, as later successional species invade oak understories and deer populations grow, oak seedlings are readily being over-topped and exhibit very low recruitment beyond the seedling stage (Abrams 1996). The continued exclusion of fire, together with competition from shade-tolerant species and browsing pressure from deer, are contributing to decreased percent composition of oak species in southern

Ontario forests. Therefore, management techniques that help recruit oak into the overstory will be important to maintaining oaks on suitable sites in southern Ontario.

Choosing an appropriate silvicultural system

The upland oaks are among the most difficult tree species to consistently regenerate successfully, regardless of the silvicultural system used. The selection of the most appropriate silvicultural system is critical for the management of upland oak forests and depends on several factors including:

- an understanding of the autecology of the desired species
- site potential or capability
- presence of advanced regeneration
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed below and summarized in **Table 6.2.2.**

Autecology of oaks

Some knowledge of the autecological characteristics of oak species described below is an important prerequisite for the selection and implementation of the most appropriate silvicultural system(s) designed to encourage successful establishment and regeneration of upland oak stands. **Table 6.2.1** summarizes more specific autecological information for five species that occur in southern Ontario and more detailed information can be found in **Appendix B**.

Reproduction and early growth of upland oak species

a) *Seeds and germination*

- Acorn production varies greatly among oak species and individual trees, and in different locations and years (Aucmoody *et al.* 1993; Sork *et al.* 1993; Dey 1995). It is influenced by weather, insects, wildlife, tree age and size, crown position, and genetics (Dey 1995).
- In many areas, predation by insects, disease, and consumption by numerous mammals and birds can substantially decrease germination of new generations, except in bumper crop years.
- Viability of seed is high.

b) *Site factors*

- Ideal seedbeds for acorns are fresh, well-drained mineral soils.
- Best germination rates occur when acorns are either three to five cm below the soil surface or are in contact with mineral soil, with a layer of leaf litter covering them (Sander 1979).
- Seedlings are more numerous where mineral soil has been disturbed (e.g., by fire or logging).

c) *Early growth*

- Germination is followed by vigorous, rapid tap-root development.
- On productive sites, where competition is often most intense and germination is greater than survival, lower understory light conditions due to high canopy closure typically result in mortality of the comparatively large cohort of young seedlings before the next bumper acorn crop occurs (i.e., within a few years (Johnson 1994)). Consequently, advanced regeneration on these sites develops from a single bumper acorn crop (Dey and Parker 1996).
- On drier, less productive sites, there may be more sunlight in the understory, but other conditions are less favorable for seed germination. As a result, fewer seedlings become established but they tend to persist for a longer time in the understory. Here, advanced regeneration may represent seedlings and seedling sprouts that accumulate and develop from several acorn crops, particularly bumper acorn crop years.
- Although oaks grow slowly in heavy shade, survival rates are relatively high in moderate shade. Here, they often develop little above the ground (i.e., the top usually dies and resprouts) but grow a large root system that allows them to grow rapidly in height once favorable conditions occur.
- Seedling survival and development are largely dependent on adequate light levels, but are also influenced by soil moisture, nutrients, levels of browsing, insect defoliation, drought, and frost (Johnson 1994; Crow 1992; Gottschalk 1988).
- They grow more rapidly under full sunlight conditions than their more tolerant associates.

d) *Sprouting*

- Since oaks are usualy difficult to regenerate satisfactorily, the use of stump sprouts as prime growing stock can help to encourage successful regeneration of these species. These sprouts, when supported by large, established root systems, represent the fastest growing form of oak regeneration (Dey 1994).
- Stump sprouts are an acceptable form of regeneration when they originate from within 2.5 cm of the groundline (Roth and Hepting 1969). Even stump sprouts originating from below the surface of the ground can produce high quality mature trees (Johnson 1994).
- Red oak is usually a prolific stump sprouter, especially trees less than 60-years- old; oaks more than 80-years-old have less than a 50 % chance of producing a competitive stump sprout (Sander *et al.* 1984; Phillips and Shure 1990). Oaks less than 20 cm DBH and 80-years-of-age are usually good sprouters. Oaks larger than 50 cm DBH sprout infrequently. The decreasing ability of oaks to sprout from stumps as they increase in age and size may be due to the inability of the dormant buds to penetrate the thicker bark of older trees (Dey and Parker 1996).

Reaction to competition

- Relative diameter growth is usually greater than that of common hardwood associates.
- Oaks have a high root/shoot ratio. The relatively higher root mass then facilitates rapid shoot growth after overstory harvest or destruction by natural forces (Johnson 1994).
- Oak is well adapted to disturbance since it has the ability to resprout, a deep root system, and thick bark (i.e., fire resistant). Stand disturbance offers oaks a competitive advantage provided that advanced regeneration has accumulated before the disturbance occurs (Larsen and Johnson 1998).
- Oak responds well to release from suppression; sapling and pole-sized dominants or codominants respond best.
- Oaks are susceptible to epicormic branching following heavy release; dominant and codominants develop fewer sprouts than suppressed trees and there is less serious development in older trees.

Factors limiting growth and development

- *Gypsy moth:* The most significant impact of gypsy moth infestation on oak is not mortality but reduced growth, yield, and wood quality (Johnson 1994). Gottschalk (1993) describes strategies designed to minimize gypsy moth impacts, including reducing the proportion of oaks in the stand, applying insecticides, and removing trees that are the preferred hosts or refuges for the insect.
- *Oak shredder*: This insect continues to cause pockets of defoliation in southcentral Ontario (e.g., 525 ha in 1997, 2078 ha in 1998, and 1,580 ha in 1999 (Howse and Scarr 1999).
- *Oak decline:* It is probably initiated by drought stress and/or defoliation and then exacerbated by further insect and disease attack (Wargo and Haack 1991). Older stands on unproductive sites are most susceptible to it (Oak and Starky 1991). There is some evidence that partial cuts in declining stands may increase the severity of decline, due partly by providing an increased food supply for shoot string root rot (Starkey *et al.* 1989).
- *Oak wilt:* This potentially lethal vascular disease is common in the Lake States. lt is spread by an insect vector (*Nutidulid* sap-feeding beetles) and may be detected in southern Ontario in the future.
- Although the oaks are considered to be relatively decay-resistant, they can be susceptible to several diseases and fungi. There are four major white trunk rots and one major brown butt rot fungi that affect red oak. Others include shoestring root rot and *Strumella coryneoides* that causes a severe girdling canker (OMNR 1998*a*). Galleries created by the carpenterworm and red oak borer may become infected with decay fungi.
- White-tailed deer readily browse oaks, often eliminating patches of regeneration. In many parts of the United States and southern Ontario, browsing by high deer populations is believed to have reduced the proportion of oak species in many northeastern hardwood forests since the time of settlement (Abrams 1996).
- Oak seedlings and saplings are vulnerable to fire, however the thick bark of older trees allows them to resist light fire damage. Burns are beneficial in re-establishing oak on a site.

Table 6.2.1. Autecology of common species in the upland oak forest cover type (Burns and Honkala 1990*a* and *b*).

Species	Red oak	Bur oak	White oak	Black oak	Chinquapin oak
Site	Well-drained, fresh, loam-silt loam	Shallow over limestone; tolerates wide range of soil and moisture conditions	Wide range of soils and sites	Fresh, well-drained soils; light, dry sands	Well-drained upland soils derived from limestone or over limestone
Canopy openings to secure regeneration/growth	Uniform canopy (60%)	Uniform canopy (60%)	Uniform canopy (60%)	Uniform canopy (60%)	Uniform canopy (60%)
Seed periodicity	2-5 years	2-3 years	4-10 years	2-3 years	4-7 years
Seedbed type	Mineral soil, humus, mineral-humus mix; best if covered with light layer of leaf litter	Disturbed litter	Humus	Mineral soil	No data
Sprouting ability	Very good	Poor	Very good	Good	Good
Likelihood of advanced regeneration	Low (upland sites only)	Common under thinned plantations	Low-moderate	No data	No data
Shade tolerance	Intermediate	Intermediate	Intermediate	Intermediate	Intolerant
Tending need	Competition	No data	Competition	Competition	No data
Self-pruning	Moderate	Moderate	Moderate	No data	No data
Response to release	Moderate (poles & saplings only)	No data	Very good (poles & saplings only)	Very good (codominant, above-average intermediate crown classes only)	Very good
Rot/stain defect	Moderate-low	Low	Low	No data	No data
Bole/form defect	Epicormics	Branching, epicormics	Branching, epicormics	Crooked stems, epicormics	No data
Decline hazard	Moderate-high	High (serious decline caused by canker, oak wilt)	No data	No data	No data
Growth rate	Moderate-fast	Slow	Slow	Slow-moderate	Slow
Wildlife values	Mast, wildlife browse	Mast	Mast, cavities	Mast, cavities	Mast

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better suited to management for other values such as wildlife habitat, that may not require timber harvesting.

The potential of the site for oak production, as suggested by the ecosite and current site and stand conditions, also helps to determine the silvicultural system of choice. Site quality assessment is an evaluation of soil characteristics (e.g., texture, drainage, fertility, depth), topography (e.g., aspect, elevation), climate, and other factors that influence growth and species composition, and ultimately provide an indication of the suitability of a site for the growth of certain species or forest types. This assessment is essential to determine the amount of effort required to manage a stand for upland oaks.

The upland oak forest type is usually found on sites with dry to fresh moisture regimes (MR 0-3). When managing for oak species, Johnson (1993, 1994) found that dry sites were considerably easier to work with because advanced oak regeneration readily accumulates. Although it is often easier to regenerate red oak on drier sites (Hilt 1985; Trimble 1973), fresh to moderately moist sites (MR 1-4) have better potential for higher quality, growth, and yield. However the latter are prone to numerous silvicultural challenges such as regeneration success and competition.

Red oak site index curves have been developed from data from forests in northern Wisconsin and Upper Michigan (Carmean *et al.* 1978), and are reproduced in **Appendix E**. Data collected in the future from growth and yield plots (**Section 7.3**) will also help to determine the most suitable ecosites for the management of oaks in southern Ontario. In the meantime, Sander (1977) provides a description of three general site quality types that may help managers assess the potential for oak production, of sites in southern Ontario. They are:

1. Good quality sites = 22 + m at 50 years. It will often be difficult and impractical to perpetuate pure oak stands on these sites because of intense competition from other species.
2. Medium quality sites = 16 - 20 m at 50 years. These sites are well suited to oak management and the perpetuation of oaks should not be difficult. It is still important to ensure that adequate advanced regeneration is established.
3. Low quality sites = 10 - 14 m at 50 years. These sites are often exclusively occupied by oaks and white pine of poor timber quality. Frequently it is best not to manage these stands or to consider encouraging mixtures of pine and oak.

The site index curves provided in **Appendix E** should not be used for coppice stands, uneven-aged conditions, or mixed species stands (E. Boysen, OMNR, personal communication, 1997).

Presence of advanced regeneration

Knowing the amount and requirements of the existing advanced regeneration on a site makes it easier to select the most effective silvicultural treatment designed to encourage successful oak regeneration, and to schedule operations. For example, red oak seedlings require one-third of full sunlight for maximum photosynthesis to occur (Dey 1994) and silvicultural treatments would need to be designed to provide this level of light. Also removal of the overstory should not occur before there is sufficient healthy oak advanced regeneration in the understory (Sander 1979; Johnson 1993, 1994; Dey and Parker 1996), and some supercanopy trees (**Section 4.4, Table 4.4.1**) should be retained in the stand.

Wildlife habitat and other natural heritage values

Upland oak forest often support many wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Tables 4.4.1**, briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Dey (1995) notes that nearly 200 wildlife species utilize acorns as a food source including chipmunks, squirrels, deer, bears, foxes, raccoons, waterfowl, woodpeckers, blue jays, and numerous insects. Oak is used by more species of wildlife than any other hard/soft mast producer.

The importance of upland oak forests is recognized by the OMNR. Current OMNR guidelines (Voigt *et al.* 1997) recommend the management of oak stands within two km of deer yards, to maintain and perpetuate mast production. Black bears may depend heavily on acorns to help them accumulate fat reserves required for hibernation. In parts of southern Ontario, acorns are also very important forage for recently re-introduced wild turkeys. Even when the provision of wildlife habitat is not a management objective, forest managers should encourage landowners to retain good mast-producing trees for the benefit of wildlife. The wildlife habitat guidelines provided in **Table 4.4.1** should be adhered to when managing oak forest cover types in southern Ontario.

Before finalizing silvicultural plans for upland oak stands managers should have a good understanding of the amount and distribution of forest cover, by forest cover type, in the surrounding local region. Silvicultural prescriptions designed to regenerate upland oak forest cover types create significant canopy openings at some time in the rotation. These open conditions can further fragment small, narrow forest patches and increase amount of edge habitat in the short-term. If the oak forest provides habitat to sensitive wildlife species, they may be negatively impacted during those times in the rotation that more open conditions prevail, and habitat loss may be inevitable. Managers need to balance objectives for regenerating and perpetuating oak species and forest cover types, against the risk of further forest fragmentation and increasing the amount of edge habitat. For small isolated forest stands (< 20 ha) with no connectivity to larger forest areas, treatments such as group selection and shelterwood that create more open conditions are less likely to create negative wildlife habitat impacts.

Other considerations

At least three other considerations, landowner objectives, available resources (e.g., financial, human, time), and the feasibility of conducting prescribed burns (**Section 8.1**), will also influence the choice of the silvicultural system for management of upland oak stands. The primary objectives for the management of most upland oak stands will likely be maintaining a significant oak component and encouraging the establishment and vigorous growth of (advanced) oak regeneration. However, many landowners and managers may have several other objectives (e.g., need for immediate generation of forest revenue, protection of wildlife habitat) that must be factored into the choice of the most appropriate silvicultural system.

In southern Ontario, the management of the majority of upland oak stands is likely to prove to be considerably more expensive and time-consuming than the management of tolerant hardwood forests because of the difficulties associated with assuring successful oak regeneration on most sites.

On many sites, the use of prescribed burns provides a competitive advantage for oaks, encourages oak regeneration, and discourages undesired competition from other species. However, in much of southern Ontario, this management tool may not be an option due to public concerns (e.g., neighbors fearing the escape of the fire) and local fire and burning regulations.

Recommended silvicultural treatments for upland oaks

Table 6.2.2 summarizes site and stand conditions and landowner objectives that help to determine the most suitable silvicultural system (i.e., group selection or uniform shelterwood) for the management of upland oak forests. If the uniform shelterwood system is chosen, and the stand is not yet mature enough to implement a preparatory cut, then the silvicultural treatment, crop-tree thinning could be considered. Crop-tree thinning, uniform shelterwood, and group selection, and their specific parameters for upland oak management are discussed in greater detail in the remainder of this section.

Table 6.2.2: Choosing an appropriate silvicultural treatment for upland oak forests in southern Ontario.

	Crop-tree thinning	Regeneration treatments	
		Uniform shelterwood	**Group selection**

Objectives for stand	• to produce high quality timber from future commercial harvests	• to develop new even-aged stand with representative component of oaks and other mid-tolerant species
		• landowner is flexibile with regard to timing of cutting treatments so that they can be done in years with good acorn crops
			• to develop patches of even-aged regeneration with some representation of oaks and other mid-tolerants, resulting in a stand with a patch mosaic of different ages (ultimately uneven-aged)
			• landowner is willing to:
			  • accept fluctuations in harvest yield by cutting cycle
			  • settle for moderate levels of oak composition to minimize risk of regeneration failure and insect damage

Site conditions	• see description for "uniform shelterwood"	• suited to medium to low quality sites with moisture regimes ranging from MR 1-4 • on good quality sites or under mesic and hydric conditions (MR 2-5), will likely require both overstory and understory density control and yet it may still be difficult to regenerate these sites to oak (Schuler and Miller 1995) • pockets of even-aged red oak/white pine exist within the stand • low risk of invasion by exotic shrubs or herbaceous vegetation	• overstory contains groups of defective or overmature trees and management for old-growth characteristics is not desired • intolerant and mid-tolerant species (e.g., basswood, white ash, red oak, yellow birch, black cherry) comprise 10 to 40 % of the stand composition and site and stand conditions are suitable for regeneration and growth of these species • low risk of invasion by exotic shrubs or herbaceous vegetation
Stand conditions	• if stand is even-aged and young (i.e., <45-years-old) then use crown touching • if stand is even-aged and >45-years-old but not within 10 years of rotation age (i.e., too young to implement shelterwood) then use crop-tree selection and thinning (based on stocking Aappendix E) to boost diameter growth and quality	• average stand DBH is 40-60 cm and/or average age is 50-100 years and it is time to consider regenerating the stand; the initial shelterwood cut should occur at least 10 years before the end of the rotation (Johnson 1994) • preferably little established or regenerating tolerant hardwoods • stands need to be large enough to permit a 30 m buffer on forest edges to protect interior habitat and reduce invasion by exotic species	• preferably little established or regenerating tolerant hardwoods or vegetation management will be required • preferably presence of sufficient healthy oak advanced regeneration • stands need to be large enough to permit a 30 m buffer on forest edges to protect interior habitat and reduce invasion by exotic species
Wildlife habitat	• see description for "uniform shelterwood"	• avoid implementation in areas where forest interior species may be negatively impacted by large canopy gaps	• avoid implementation in areas where forest interior species may be negatively impacted by large canopy gaps
Aesthetic considerations	• produces a more uniformly spaced stand with less diversity of sizes; crop trees will likely have paint on them	• most of the high forest canopy will be lost for a period of time following removal cut(s)	• stand develops patchy appearance and a significant proportion of high forest canopy is always maintained
Landowner follow-up commitment required	• when the even-aged stand must be regenerated either by uniform shelterwood or group selection	• frequent understory vegetation control to minimize undesirable species competition • may also need to consider supplemental planting where natural regeneration is not sufficient	• frequent understory vegetation control in openings to minimize undesirable competition • may also need to consider supplemental planting to boost stocking where natural regeneration in canopy gaps is not sufficient

Crop-tree thinning

In even-aged stands, thinning can be conducted using a crop-tree approach. Crop-tree thinning considers individual trees as candidates for a final crop and releases their crowns to allow for the development of high value products (Anderson *et al.* 1990). Two techniques can be used to accomplish crop-tree management:

1) Where even-aged upland oak stands are less than 45-years-old, the crown touching method is recommended.
2) In stands older than 45-years-of-age, but not yet within 10 years of rotation age (or where most trees have not yet reached 80 % of the rotation diameter), crop-tree management can be accomplished by thinning to specific residual basal area levels, determined by consulting the specific stocking guides for red oak given in **Appendix E**.

In general, thinning should be done by creating canopy gaps no larger than 1.5 m wide on three or four sides of selected crop trees (Sampson *et al.* 1983). Both thinning techniques are discussed in detail below. Regardless of technique, thinning should never reduce crown closure in upland oak stands below 70 %.

In stands that contain many stems from stump sprout origin, stump sprout thinning should be considered if high quality wood production is a management objective. Since stump sprout thinning is most economically conducted at the same time, it is also discussed in this subsection.

When to begin thinning

Thinning in young stands should be undertaken conservatively soon after crown closure but not until dominant stems can be recognized. Nyland and Marquis (1978) warn that ill-conceived early thinning treatments can delay natural pruning and promote epicormic branching, low forking, and sunscald. Furthermore it should only be conducted when it is necessary to maintain survival and stocking of potential crop-quality trees (Anderson *et al.* 1990).

Usually stands that have originated from advanced regeneration or seedlings do not need to be thinned prior to stand age 45 (Hibbs and Bentley 1983) and in some cases thinning prior to this could reduce potential financial returns because the value gained in additional diameter growth resulting from the thinning will not compensate for the value lost in merchantable height from lack of self-pruning (Hibbs and Bentley 1983). They suggest a rotation of about 95 years would maximize returns. Therefore the timing of first thinnings in even-aged upland oak stands is a compromise between shortening the rotation period and optimizing the effects on bole quality and value (Anderson *et al.*1990).

Where oaks are overtopped by long-lived competitors early in a rotation, early release may be necessary for oaks to attain dominance. Where this occurs, Miller *et al.* (1998) recommend deferring thinning until the 20- to 60-year-old codominant trees average 7.6-9.1 m tall.

Crown touching method

In southern Ontario, this method is recommended for use in stands less than 45-years-old. All trees, except another crop tree, with crowns touching or overlapping above or below the crown of a crop tree, are removed. Generally tree removal is only warranted if it will benefit a crop tree. This type of release can provide the crop trees with up to twice the diameter growth of the surrounding, unreleased trees (Anderson *et al.* 1997).

Silvicultural objective

In young even-aged stands (e.g., polewood to small sawtimber) or where precommercial harvests are under consideration, it is best to base these thinnings on a crop-tree approach, to focus future growth on trees with the best opportunity to increase in quality and value. Crop-tree thinning releases crowns to allow for the development of high value products (Anderson *et al.*1990). Crop trees can also be selected to meet wildlife, aesthetics and other management objectives (Perkey *et al.* 1993)

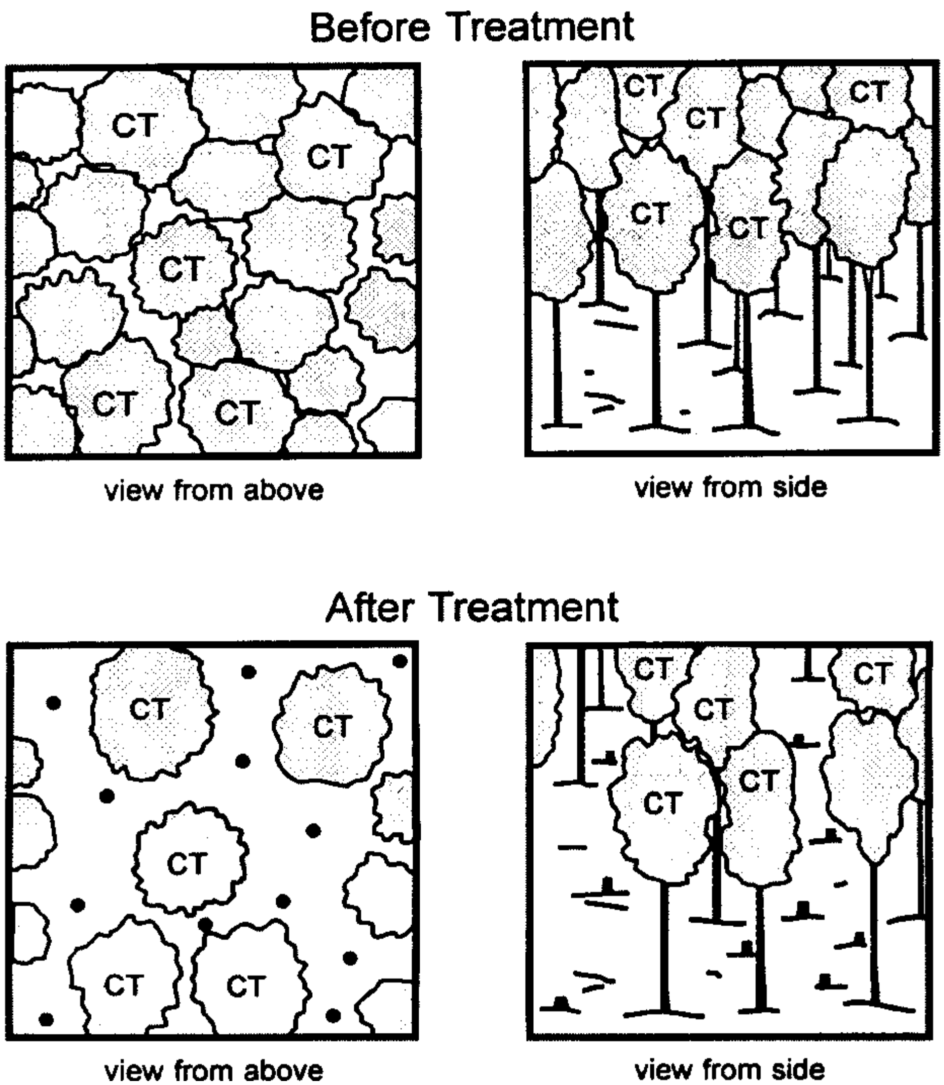


Figure 6.2.1: A schematical representation of a stand before and after treatment by crown touching method (from Perkey *et al*. 1993).

Number of crop trees to leave

In southern Ontario, it is recommended that 250 crop trees be selected per hectare in precommercial operations. This permits long-term maintenance of approximately 150 crop trees per hectare (Anderson *et al.*1990).

Selecting crop trees

Based on research by Perkey *et al.* (1993) and Anderson *et al.* (1990), the following recommendations will help tree-markers choose oak crop trees for both timber and wildlife values:

- Select dominant and codominant trees of at least eight meters tall, with all species well-suited to the site.
- Crop trees should be vigorous with healthy, large crowns and no dead branches in the upper crown.
- Only select stump sprouts that originate at or below 2.5 cm of the groundline and have U-shaped connections (see **Figure 6.2.2**) to other sprouts.
- Butt logs of crop trees should have grade one or two potential with no epicormic branching or serious defects.
- Do not select high-risk trees (e.g., leaning, splitting forks).
- Selected crop trees should have a life expectancy of at least another 20 years.
- Select crop trees from all the existing species suited to the site, in order to provide more stable mast crops and reduce the risk of total crop failure from damaging agents such as gypsy moth.
- To control gypsy moth, consider reducing oak composition below 50 % on those sites most susceptible to mortality (e.g., those with mesic soil conditions) and maintaining crop trees with vigorous crowns by timing thinning treatments to occur before stem exclusion or significant decreases in annual incremental growth occur.
- Where both red oak and white oak occur in the same stand, select a greater proportion of white oak crop trees if the primary management objective is the provision of wildlife habitat because acorns of the latter species are preferred by more wildlife. Select a greater proportion of red oak crop trees if timber production is the primary objective because red oak is both a high value crop species that responds with fast growth and improved quality and one of the highest producers of preferred mast; white oak timber quality generally does not improve following crop-tree thinning.
- Consider retaining black oak trees where these are found because the softer wood of this species makes cavity excavation easier and likely to occur. Also retain longer-lived white oak and hickory trees because cavities in these species will be available for a longer period of time.

Figure 6.2.2: Difference between V-type (left) and U-type (right) connection in coppice stems.

S. Reid

Stump sprout thinning

Those stands being managed with concern for future wood quality, and containing many stems from stump sprout origin, should receive a stump sprout thinning. This thinning can be timed to coincide with any cleaning and/or weeding, thereby minimizing the number of site visits. Before prescribing stump sprout thinning, managers should evaluate whether the site potential warrants the added expense of this silvicultural treatment. If an assessment of site, suggests that stump sprout thinning would be economical, the recommendations listed in the following should be used.

Site potential - will stump sprout thinning be worthwhile?

Modelling studies by Dwyer *et al.* (1993) found that precommercial thinning of stump sprouts in the Ozark Region was not an economical management practice. Therefore managers would be wise to select their sites carefully and keep track of the time and money spent on stump sprout thinning treatments. Johnson and Rodgers (1984) noted that these treatments should be limited to locations with a site index of at least 20 m, at age 50 years. Johnson and Rodgers (1980) estimated that for productive sites in Wisconsin (e.g., site index 21), early clump thinning of red oak (i.e., in stands of < 20 years) to one stem would produce a commercially mature stem 20 years earlier than for unthinned stump sprouts. Johnson and Godman (1983) also recommend selecting stands for stump sprout thinning on more productive sites.

When to thin stump sprouts

Johnson and Rodgers (1984) discovered that clumps thinned to one stem before they reached 8 cm DBH (12- to 15-years-of-age) maximized residual stem growth. Johnson and Godman (1983) suggested thinning sprouts when they reach 5 cm DBH and definitely before they reach 7.5 cm DBH. Similarly, Stroempl (1983) recommended thinning clumps of stump sprouts when they are 10- to 20-years-old.

How to do stump sprout thinnings

Stroempl (1983), Lamson (1988), and Johnson and Godman (1983) provide the following clump thinning recommendations:

- After a harvest, high stumps can be re-cut to the ground to encourage more sprouts to develop from below the ground.
- To produce desirable seedling sprouts, cut damaged or otherwise unsuitable advanced growth during cleanings.
- It is most practical to thin to two to three sprouts/clump before age 20 years and then reduce the clump to a single stem.
- For crop-tree stems, select the largest single stem that:
    - is dominant or codominant, straight, free of forks, with little evidence of epicor mic branching, and no defects in the lower five meters of bole
    - originates as low as possible on the stump (i.e., Johnson (1994) recommends that stems should not originate any higher than 2.5 cm from the groundline)
    - is not connected to another stem, but well attached to the stump at or below ground level.

- If two sprouts are selected, they should have U-type connections between them. V-type sprout connections, which will fuse together at a common base as they grow, should be treated as a unit, either leaving all the stems or cutting all the stems (see **Figure 6.2.2**).
- Stump sprouts should be cut as low as possible with a saw and bark damage should be avoided.
- Thin around crop stems to provide sufficient growing space and to optimize future growth and quality by removing all surrounding intermediate or codominant stems if their crowns touch the crop-stem crown or if their crowns are above or below the crop-stem crown.
- Thin around thinned clumps again in approximately 10 years.

Thinning with use of stocking guides

Section 5.2 provided an introduction to thinning with the use of stocking guides for even-aged stands. Stocking guides are charts that show the relationship among basal area, number of trees, and average tree diameter. Managers can use them to determine current stand stocking and the amount of basal area that can be removed by thinnings. A red oak stocking guide can be found in **Appendix E**.

Stocking guides usually use three curves to represent stocking levels:

- The "A" curve represents maximum stocking for undisturbed stands of average structure.
- The "B" curve is the lower limit of stocking needed for full occupancy of the site by trees with fully developed crowns that just touch each other.
- The "C" curve represents stocking levels that should reach the B level within 10 years (Gingrich 1967).

Managers should know the current stand density (i.e., the number of trees per hectare), derived from the stand inventory, and the average stand diameter, and use them to determine the desired residual stand conditions needed to optimize stand growth. In stands 45-years-of-age and older, managers should thin stands by reducing the density to B-level stocking every 10 years or so, depending on the time interval required for the stand to reach A-level stocking. Thinning below the B-level risks increasing epicormic branching on the lower bole, decreasing tree value (Johnson 1994), and may underutilize the growing space in the stand.

Thinnings should continue until the stand is ready for the development of oak regeneration (Hibbs and Bently 1983; Sampson *et al.* 1983).

Sander (1977) makes the following recommendations:

- When the stand has acceptable stocking above the C-level, the stand is worth managing.
- Sawtimber stands that are understocked (i.e., below the B-level) or of poor quality should be rehabilitated, regenerated, or left unmanaged.
- If the majority of the stand is less than 80 % of the desired diameter, it should be thinned unless stocking is not much above the B-level.

- In general, leave 60 % stocking (B-level) following thinning.
- Thinnings should be done from below and should leave the best trees spaced uniformly throughout the stand.
- Stands with a regular thinning history should not be thinned beyond three-fourths of the rotation age (50 to 70 years) or when most trees have reached 80 % of the rotation diameter, depending on the site. After this time preparatory and/or regeneration cuts to develop advanced regeneration by the uniform shelterwood silvicultural system must be started (or the stand can be considered for group selection treatments).

Regeneration treatments

Either uniform shelterwood or group selection are appropriate silvicultural systems for regenerating oak upland stand once most trees in the stand have reached maturity. Refer to **Table 6.2.2** for guidelines to determine which system is most appropriate.

Regardless of the silvicultural system chosen for regenerating upland oak stands, many factors such as poor seed years, seed losses to animal predation, dessication or disease, heavy weed competition, spring droughts, and deer browsing can lead to regeneration failure. Vegetation management to control competing species and/or supplemental planting may be necessary to obtain adequate stocking of oak advanced regeneration. Managers will need to monitor sites where regeneration cuts (for uniform shelterwood) or group openings (for group selection) have been done to determine whether follow-up treatments will be required. If planting is required, seedlings should be obtained from a seed zone as close as possible to that of the planting site (**Figure 4.1.4**). A decision to control competing vegetation or supplement natural regeneration by planting should be made within three years of implementing a regeneration treatment.

Uniform shelterwood system

When applied to the regeneration of upland oak sites, the shelterwood system is intended to mimic the ecological conditions created by fire, insect, or disease damage, and mortality that lead to a more open forest canopy. Successful application of this method often depends on imitating the effects of successive understory fires that likely provide competitive advantages to oak regeneration.

Readers are advised to refer to Dey and Parker (1996) for more detailed information about the management of red oak by the uniform shelterwood system. It includes a literature review and examination of some experiences in Ontario. The following discussion is largely based on this information source.

Silvicultural objective

The shelterwood cuts are designed to further the development of oak advanced regeneration by regulating the level of sunlight at the forest floor. Managers vary the frequency, number, and intensity of shelterwood harvests to encourage oak advanced regeneration and discourage understory competition. It is important to maintain sufficient crown closure to control competing vegetation until oak seedlings are well established. In natural regeneration prescriptions, on sites where oak advanced regeneration is sparse, a three-cut shelterwood may be used; the first thinning is a regeneration cut to increase crown exposure to sunlight of good acorn producers (Dey 1995). Once the oak seedlings are established, the shelterwood is created. Managers should strive for moderate levels of oak composition to offset problems with regeneration and health.

Regeneration cut(s)

The regeneration or seed cut is designed to secure sufficient regeneration of the desired oak species. More than one regeneration cut may be required before adequate levels of advanced regeneration are obtained. There are three important aspects to the regeneration cut(s):

1. cleaning or weeding the understory
2. thinning the overstory to maximize future acorn production and provide optimum light conditions for oak seedling growth
3. timing the operation to coincide with a bumper acorn crop

Each of these is discussed in the following.

1. Cleaning or weeding the understory

As a result of fire suppression, passive management, and few other forest stand disturbances, oak forest understories in southern Ontario are often dominated by maples, beech, and other shade-tolerant trees and shrubs. Therefore, most non-oak subcanopy tree and understory woody vegetation should be removed in conjunction with the prescribed overstory reductions to promote oak regeneration (Sander 1979; Loftis 1983; 1985). Exceptions to this practice might include portions of the stand where microsite conditions are unsuitable for oak species (e.g., wetter, deeper soils). Removal of the non-oak subcanopy trees with such tools as herbicides, prescribed burns, and brushsaws, should be started and possibly completed prior to the regeneration cuts and definitely before any removal cuts (see **Section 8.1** for information on these vegetation management techniques)**.**

2. Overstory thinning

To achieve successful natural regeneration of oak, a residual crown closure of 60 to 70 % must be maintained after the regeneration cut to allow sufficient sunlight to penetrate to the forest floor to permit the establishment of oak seedlings and control the growth response of competing species. The retention of full-crowned oaks in the overstory provides the light shade, or "shelterwood" needed to inhibit understory competition and ensures optimum acorn production in years of good seed crops, approximately every three to five years (Dey and Parker 1996). As site quality increases, a denser residual overstory is required to prevent the release of undesirable vegetation (Loftis 1990).

Production of acorns by individual trees is most closely correlated with crown size and the amount of crown surface that receives sunlight (Johnson 1994). In upland oak stands in central Ontario, one-half of the estimated acorn production comes from 13 % of the overstory oaks with diameters of at least 40 cm DBH. In general, maximum acorn production occurs in mature stands (50- to 100-years-of-age) where oaks are 40 to 60 cm DBH and comprise 55 % or more of the stand stocking. Therefore, to maximize acorn production in mature stands being managed by the shelterwood system, stands should be thinned to leave approximately 141 oak trees of 40 cm DBH or 68 trees of 60 cm DBH per hectare (Dey 1995).

Dey (1995) recommends oaks with the following characteristics be considered for retention as acorn producers during shelterwood harvests or intermediate thinnings:

- dominant and codominant trees
- trees known to be good acorn producers
- trees with large, healthy crowns
- trees with abundant foliage and live branches
- trees between 40 to 60 cm DBH
- 50- to 100-year-old trees

3. Timing of overstory thinning and understory cleaning treatments

If possible, regeneration cuts should be conducted in bumper or good years for acorn production to ensure adequate seed in spite of insect and animal predation (Dey and Buchanan 1995). To estimate the quality of a seed crop in a given summer or fall, landowners or managers could randomly locate enough samples, well distributed throughout the stand, by either of the following methods:

- in the fall, 1 m^2 plots on the forest floor that are used to count the number of acorns or acorn caps
- in the summer, tree plots used to count the number of acorns on a random 60 cm length of branch terminal

Then, by averaging the counts obtained for the total number of samples, the seed crop rating can be estimated from **Table 6.2.3**. The distribution of acorns on the forest floor is highly variable because acorns tend to fall within a tree-length of the parent tree and often collect in small depressions on the forest floor or are concentrated on the downhill side of oaks (Dey and Buchanan 1995). It is important to locate a large enough sample size to account for this variation. Fall counts of acorns or acorn caps on the floor do not account for overwinter losses of acorns to predation, disease, or desiccation.

Where competing understory vegetation is abundant, managers should maintain at least 70 % residual crown cover (Arend and Scholz 1969; Lorimer 1989). Where understory competition has been removed or is sparse, initial harvests can leave as little as 50 % residual crown cover (Arend and Scholz 1969; Wolf 1988). Sander (1979) observed the need for shelterwood prescriptions to be tailored to specific species and ecosystems.

Table 6.2.3: Guide for rating red oak acorn crops (from Dey and Buchanan (1995)).

Crop rating	Number of acorns/ha (thousands)	Average number of of acorns/m^2	Average number of acorns/60 cm branch tip
Bumper	>600	>60	= 25
Good	300-600	30-59	17-24
Fair	160-300	16-29	9-16
Poor	50-160	6-15	4-8
Trace to none	<50	<5	<3

Seedbed preparation

Seedbed preparation is not necessary for oaks. However, summer or fall logging appears to benefit oak establishment by increasing mineral soil exposure, tramping advanced shade-tolerant regeneration, and burying acorns.

Controlling competing vegetation

Control of competing vegetation is also essential. Cutting treatments often result in rapidly growing sprouts that continue to pose a competition problem. Reduction of understory competition improves the rate of growth for seedlings and new sprouts by helping to ensure they receive sufficient moisture and sunlight. Jacobs and Wray (1992) suggest a method to evaluate the severity of understory competition. If 30 % of a series of 6 m^2 circular plots used to inventory the understory vegetation are dominated by competing species and the oak regeneration is less than 30 cm tall, control of competing understory vegetation is highly recommended. Where oak regeneration in the plots consists of mainly stump sprouts and regeneration is greater than one meter in height, understory vegetation control is only necessary when 70 % of the plots are dominated by undesirable species.

Herbicide treatment and prescribed fire are the two most effective means of controlling the competing vegetation and maintaining the growth of the desired oak species. Further details on vegetation management treatments are provided in **Section 8.1**, but details more particular to regenerating oak by use of prescribed fire are provided here. Unfortunately, in many parts of southern Ontario that are now dominated by agricultural and urban land uses, prescribed fire is not a feasible option. Instead, managers use manual cutting and/or herbicides to mimic the effects of ground fires.

Prescribed fire

Prescribed fire is used to control understory competition for sunlight and reduce the regeneration potential of non-oak species. Periodic understory burns create a more open environment on the forest floor by reducing the amount of understory vegetation, especially on mesic sites (MR 2-4), where oaks can be considered to be fire subclimax species. Oaks can survive high intensity and repeated burns because they have a large supply of dormant buds at the root collar (Korstian 1927) and a large root system (Dey and Parker 1996). The dormant buds are protected from the heat of the fire by being located in the mineral soil (Little 1974). These characteristics provide oak with a competitive advantage over hardwood species that have fewer, more exposed buds, and smaller root systems. Prescribed fires do not increase the number of advanced oak regeneration but they do improve their vigour, form and height growth (Brose and Van Lear 1998).

The number of burns required to effectively control competing understory vegetation is unknown but research and experience suggest that on most sites, a minimum of two burns is required to reduce the competition (Dey 1994*b*). In one multi-burn trial near Bracebridge, Ontario, Mutchmor and Morneault (1995) found that there was no improvement in advanced oak regeneration after two consecutive spring prescribed burns. Research by Nyland *et al.* (1983) indicated that two burns, four years apart, effectively controlled competing understory vegetation and oaks were able to resprout and grow without serious difficulty. Dey and Parker (1996) recommend scheduling prescribed burns every three to five years; shorter return intervals have indicated no improvement in oak regeneration.

Studies in Ontario have shown that fire-caused mortality of red oak decreases with age; seedling mortality was 30 % for three-year-old seedlings (Dey 1994*b*, Mutchmor and Morneault 1995) and up to 70 % for one-year-old seedlings following a spring burn (Johnson 1974, Mutchmor and Morneault 1995). For this reason, Dey and Parker (1996) recommend that burns be conducted either right before a good acorn crop or three years following a good crop, to allow sufficient time for germination and seedling establishment.

When selecting a site for prescribed burning, the following factors should be considered:

- *Site type:* Sites that are good candidates for red oak shelterwood management and that are drier and less herb-rich will likely need fewer fires to promote red oak regeneration than the moister, richer sites with a higher component of hardwoods (OMNR 1998*a*).
- *Understory distribution and species composition of shrubs and hardwood regeneration:* Used to assess competitiveness of site and potential for the need for more than two burns or a follow-up chemical/manual tending treatment. Spring prescribed burns of low to moderate intensity can kill balsam fir from 3 to 15 cm in basal diameter (Methven and Murray 1974) and the above ground portion of hardwood shrubs and trees up to 10 cm in diameter (McCarthy and Simms 1935, Lotti *et al*. 1960) depending on the local fire intensity and stand conditions. Although the conifer understory is easily killed by fire, hardwood trees and shrubs resprout. Some species sprout more vigorously than others. Hazels are very vigorous sprouters and can only be reduced by repeated summer burns (Van Wagner 1963, Buckman 1964). Basswood, red oak and white birch are vigorous sprouters while elm, bur oak, ironwood, and red maple are slightly less vigorous (Perela 1974). The least vigorous sprouters are sugar maple, beech and yellow birch (Perela 1974).
- *Presence of advanced oak regeneration:* prescribed fire is most effective when advanced oak regeneration has a well established root system (three years or more).
- *Access:* Must be adequate to move people, fuel and equipment at a reasonable cost.

- *Values:* Check for values that may need to be protected or where people must be notified about the prescribed fire.
- *Boundaries:* Good natural boundaries (low, wet area in spring, creek, river) reduce the complexity and cost of a burn.
- *Water sources:* A good water source for suppression. Can be as small as a creek or pond, but its suitability should be checked if it is likely to be seasonal.
- *Topography and slope:* Used to assess difficulty of burning, layout of ignition lines, and potential scorch damage to overstory trees.
- *Size of area:* Will affect resources needed for the burn and the burn cost.

The *Prescribed Burn Planning Manual* (OMNR 1996) describes the planning process, content of an operational plan, and process for public input and review into the plan. This manual should be reviewed when considering prescribed burning as a silvicultural treatment on crown land.

Advanced regeneration

During the time period between the initial regeneration cut and the first removal cut, sufficient numbers of healthy seedlings of the desired species should be accumulating. It is important to monitor seedling density, distribution, growth, and competition, and to intervene when necessary to produce a cohort of desirable regeneration that can respond and dominate the site following overstory removal. The status of oak advanced regeneration can be used to time additional shelterwood cuts including final overstory removal (Dey and Parker 1996).

Sander (1979) suggests that overstory stocking can be reduced to 50 % when the advanced oak regeneration is about 0.9 m tall. In the upland oak forests of the midwestern United States, adequate advanced oak regeneration must be at least 1.4 m tall or 13 mm in diameter at ground level (Clark and Watt 1971; Sander 1971, 1972; Sander *et al.* 1976). Stems of this size or larger will more likely produce reproduction in the dominant and codominant crown classes (Sander *et al.* 1984). Approximately 1075 stems per hectare are required to produce a polewood stand containing 30 % oak by basal area (Sander *et al.* 1976).

According to Clarke and Watt (1971), the seeding cut and subsequent tending and regeneration treatments should focus on producing 1,000 to 10,000 advanced oaks and other target species per hectare. These seedlings should be at least 0.70 to 1.5 meters tall and above the competition.

Although the actual number of required oak advanced regeneration will really depend on factors such as the pre-harvest size of the regeneration, desired level of oak stocking, site conditions and quality, and management intensity, generally higher stocking and larger stems of oak advanced regeneration are required as site quality, competition, and desired level of oak stocking increase; and management intensity decreases (Dey and Parker 1996).

Oak regeneration may still be successful with smaller stems of oak advanced regeneration but Dey and Parker (1996) report that there are numerous examples of oak regeneration failures despite abundant small advanced regeneration.

Expected stump sprouts from trees to be removed in the harvest cut can compensate for deficiencies in advanced oak reproduction. **Table 6.2.4** was developed to assess oak regeneration potential from stump sprouts in the Missouri Ozarks (Sander 1989). To use this table, find the expected proportion of stumps that will produce one codominant stem, based on the site index and parent age of the stand for each diameter class of trees that will be harvested. Multiply this number by the number of trees per hectare in the diameter class that will be harvested. Add these values for each diameter class to be harvested to determine the expected contribution that stump sprouts will make to advanced regeneration following harvesting. The values in **Table 6.2.4** should be used with caution since they were not derived from data from southern Ontario oak stands. If advanced regeneration numbers are still too low, then underplanting can be used to increase the quantity of oak.

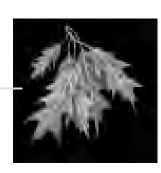
For underplanting, Johnson *et al.* (1986) recommends an overstory stocking of 55-65 % with removal of all low competition and subcanopy shade tolerant tree species. He also suggests planting seedlings from 0.7 to 1.3 m tall, with a 10 mm diameter at 2 cm above the root collar.

Removal cut

One or more removal cuts are used to release the advanced regeneration. When the overstory is closed, more than one removal cut may be required to maintain good crown form of seedlings (Bey 1964). Generally final overstory removal should not occur until advanced growth is well established. In Elliott *et al.* (1997), Ralph Nyland suggests that final overstory removals should occur six to ten years after the regeneration cut and before saplings reach 2.5 cm DBH. Often, the final removal cut should not occur before regeneration reaches waist height (0.70 to 1.5 m) and certainly should be completed before these saplings reach 4.6 m in height (Elliott *et al.* 1997).

Black oak and white oak growing in xeric (i.e., drier) ecosystems (MR 0-1) may require two or more decades before they accumulate the root mass necessary for competitive shoot growth after overstory removal. Delaying the final overstory removal inhibits oak reproduction and favors the shade-tolerant species. Furthermore, late removals make larger regeneration more susceptible to severe logging damage that will significantly reduce oak stocking levels. Also removal and release cuts should be carried out when the ground is frozen to protect advanced regeneration.

It is not necessary or always desirable to remove the entire overstory in the final shelterwood cut. A few supercanopy trees (5 to 35/ha or up to 6 m^2/ha) left standing may be important for wildlife, aesthetics, and long-term seed sources. Although these trees will have little impact on the development of the new stand, their survival into the next generation helps to mimic natural processes occurring in the forest stand (Dey and Parker 1996).



Suggested modifications for unique stand conditions

Management of upland oak stands by group shelterwood system

Silvicultural objective

To maintain patches of oak trees in an existing stand that may not be dominated by oak species, and where these are unevenly distributed throughout the stand (e.g., on hilltops).

Site description

See the discussion earlier in this subsection of site productivity or capability for a description of suitable sites within a stand where this modification of the shelterwood system is applicable.

Silvicultural prescription

The group shelterwood system creates patch openings (i.e., canopy gaps) to accomplish oak regeneration objectives. The patches have diameters of 1.5 to 2 times the height of the canopy (i.e., opening is equal to or < 60 m across). The location of patch openings should follow the same guidelines as for the location of openings for group selection, discussed in the following section; guidelines for harvest regulation are also the same. Each patch is carried through the series of shelterwood system treatments described previously for the uniform shelterwood system, creating regeneration under the protection of an overstory.

The area between the shelterwood groups can be left to maintain higher stocking levels, large-diameter trees, and/or old-growth features or they can be treated with the group shelterwood system during future cutting cycles. Future patches should be placed against shelterwood patches from previous cutting cycles.

Less than 10 to 20 % of the stand area should be treated as new patches during any one cutting cycle. To minimize both invasion by exotic species and dessication, a buffer of 20 m or more should be left untreated around the forest edge. This silvicultural prescription should not be applied in the interior of core forests.

Table 6.2.4: Expected proportion of stumps that will produce at least one codominant or larger stem at age 20 based on data from the Missouri Ozarks (Sander 1989).

Species	Site index (m)	DBH class (cm)	Age of parent tree (years)			
			40	60	80	100
Black oak	15	5 – 13	.36	.34	.32	.30
		15 – 30	.13	.11	.10	.08
		30 – 40	.06	.05	.04	.03
		43 +	---	.02	.02	.01
	18	5 – 13	.47	.45	.42	.40
		15 – 30	.16	.15	.13	.12
		30 – 40	.07	.06	.05	.04
		43 +	---	.03	.02	.02
	21	5 – 13	.61	.59	.56	.54
		15 – 30	.21	.19	.17	.16
		30 – 40	.19	.08	.07	.06
		43 +	---	.06	.04	.03
White oak	15	5 – 13	.47	.25	.12	.05
		15 – 30	.18	.10	.06	.03
		30 – 40	.06	.04	.03	.02
		43 +	---	.02	.01	.01
	18	5 – 13	.63	.38	.19	.08
		15 – 30	.26	.16	.09	.05
		30 – 40	.09	.07	.05	.03
		43 +	---	.03	.02	.02
	21	5 – 13	.81	.55	.31	.15
		15 – 30	.36	.25	.16	.09
		30 – 40	.15	.11	.08	.06
		43 +	---	.05	.04	.04
Red oak	15+	5 – 13	.86	.86	.49	.49
		15 – 30	.86	.86	.46	.46
		30 – 40	.86	.86	.38	.38
		43 +	---	.86	.24	.24

Group selection system

While this method has been used to successfully manage upland oak forests, most research from the northeastern and central United States suggests that the shelterwood system is preferable. In southern Ontario, oak is usually a difficult species to regenerate in openings, except on very dry sites. Therefore group selection is not recommended if the objective is to create an oak stand. However, it is a potential silvicultural option if the objective is to establish and maintain a component of oak within a larger tolerant hardwood stand, where site and stand conditions imply that this is highly possible.

The following disadvantages of the group selection system should be carefully considered when deciding whether to use this method for management of the upland oak forest type:

- Openings create a large amount of edge that can promote epicormic branching and lead to decreased log quality on residual trees that surround the openings.
- After a number of cutting cycles, it becomes increasingly difficult to mark stands to prescribed residual basal areas because of the challenge of finding sufficiently large areas left to make group openings. This could lead to large fluctuations in yields during some cutting cycles (Roach 1974).
- Unscrupulous operators have used group selection terminology to describe practices that are actually high-grades and diameter-limit cuts (Elliot *et al.* 1998).

Silvicultural objective

This method can be applied to good quality sites, including those with extensive shade-tolerant regeneration (e.g., sugar maple, beech) that prove costly to regenerate and manage uniformly across the stand using the uniform shelterwood system. It will appeal to landowners who want to regenerate oak on upland sites but do not want heavy or total canopy removals that occur with shelterwood methods. Group selection also allows regeneration within more manageable and aesthetically acceptable small openings.

Although this method can maintain an oak component on better sites, managers should not always *expect* the dominant cover type to be oak. Also, the group openings will require intensive management to ensure success.

Regulation of periodic harvests

See the 'Harvest regulation' discussion in **Section 6.1**, 'Group selection system', for detailed instructions on determining the amount of harvest.

Location of openings

The information collected during the stand inventory will prove useful for determining locations of the group openings. These group openings will create a new age class (e.g., seedlings). Again managers should concentrate their efforts on sites best suited to upland oaks.

There are several guidelines that can be used to determine where they should be located.

- First mark and remove the patches of poorest quality or unhealthy mature trees (i.e., areas where growth and returns are low compared to the rest of the stand (Miller *et al.* 1995).

- If patches of existing oak regeneration of target size are present, locate opening to release them.
- Provide openings in the path of significant seed sources of desired species, to be timed with seed years.
- Locate openings in areas with excessive numbers of trees from a particular size class (Law and Lorimer 1989).
- Try to space the openings fairly uniformly across the stand (Miller *et al.* 1998).
- Consider aspect. (**Table 6.1.9**) On north-facing slopes use openings of a size towards the large end of the suggested range (see "Size of openings" below) to increase the amount of sunlight reaching the floor; on south-facing slopes use openings of a size towards the small end of the suggested range to minimize desiccation of regenerating seedlings, especially during periods of drought.
- Maintain sufficient distance between edges of openings (i.e., minimize long, narrow openings) to prevent shading from reducing the amount of required sunlight to promote regeneration of the desired oak regeneration within the opening (Miller *et al.* 1998).
- New group openings should be placed against previous openings to:
    - avoid promoting epicormic branching in unopened portions of the stand because this reduces timber quality)
    - minimize wind and ice damage (Miller *et al.* 1998)
- Consider the limitations imposed by the landscape, wildlife habitat concerns, and aesthetics and how there might affect silivicultural activities.
- Buffers of at least 30 m should be left around the forest edges to minimize both invasion of exotic species and dessication.
- In large woodlands, group openings should not impact on core areas identified for interior habitat conservation.

Size of openings

Researchers have tested a wide range of opening sizes (Dale *et al.* 1995; Leak and Filip 1977; Minckler 1989) and **Table 6.1.10** summarizes some of these studies on red oak. The results tend to indicate that larger openings up to or greater than twice the height of the stand provide conditions suited to the regeneration of intolerant species such as poplar, white birch, black cherry, and tulip tree. Smaller openings of less than one-half the stand height create conditions best suited to tolerant species including sugar maple, red maple, beech, and hemlock (Dale *et al.* 1995; Minckler 1989).

Minckler and Woerheide (1965) studied oak stands with 10-year-old group opening diameters ranging from 25 to 200 % of tree height and found that opening size had little effect on number of stems of reproduction but strongly affected species composition of saplings taller than 3 m. Opening diameters greater than 100 % of tree height had little added effect on species composition or reproduction growth. In smaller openings, growth was less and shade-tolerant species were more prevalent.

Minckler (1989) re-examined the same trial after 40 years and found that the red oak saplings taller than 3 m were most abundant in gaps of about 100 % of tree height. He concluded that regeneration in canopy openings with diameters from 100 to 200 % of tree height was successful in terms of species, tree numbers, and growth and that larger openings are not usually required or appropriate.

The upland oaks are generally mid-tolerant of shade and the associated hickories range from mid- to intolerant. To encourage regeneration of these species, group openings should provide a minimum of one-third of full sunlight (Law and Lorimer 1989).

It is recommended that forest managers try to create openings with diameters from 1 to 2 times the average canopy tree height and vary their location according to local topography of the stand. For example, Law and Lorimer (1989) note that aspect and other site conditions can affect the size of openings required to provide one-third of full sunlight (i.e., an opening on a north-facing slope will receive less sunlight than a similar-sized opening on a south-facing slope). See **Table 6.1.9.**

Shape of openings

The shape of group openings can vary but more round or square gaps may provide better light conditions for regeneration than longer, narrower gaps that result in increased shading in the opening.

Number of openings at each periodic harvest

This will be determined by the regulation. See the heading “Harvest regulation” in the discussion of group selection in **Section 6.1**.

Harvesting and seedbed preparation of openings

Openings should be cleaned by removing all trees 2.5 cm DBH or greater (Miller *et al.*1995). Advanced regeneration should be carefully protected. As with the shelterwood treatments, the presence of advanced oak regeneration prior to creating the group openings improves success of this system (Sander and Clarke 1971). Take care to avoid skidding through regeneration established in previously cut openings.

For stands or portions of them without advanced regeneration, it is likely that some form of site disturbance will be necessary to improve the seedbed and promote oak regeneration. This can be accomplished through the harvesting activity, additional scarification, or prescribed burning. These site preparation treatments should be conducted prior to or during the harvest operation. Harvesting during the summer/fall seasons may provide the best site preparation.

Treatment between group openings

The decision to conduct improvement cuttings between the group selection openings depends on overall stand management objectives. Sometimes wildlife habitat requirements or operational limitations make it difficult to improve by thinning, the growing conditions of the area between the group selection openings.

With mid-tolerant species such as the upland oaks, thinning between groups may actually encourage the development of tolerant regeneration that can become a competition problem when those areas are later placed in group openings. However, some light improvement to remove trees with infectious diseases will improve economic returns and reduce overall stand health problems.

Care must be taken to ensure that residual basal areas are kept higher in the uncut areas between group openings to compensate for the openings. Miller *et al.* (1995) suggest that trees with the following defects or characteristics be removed in these areas to improve overall stand quality:

- culls and near culls, unless they provide wildlife habitat
- trees with significant rot in the butt log (> 40%)
- low-grade trees that are not expected to attain sawlog quality
- short-lived species or other species with low vigor that are expected to die before the next periodic cut
- invasive exotic species

Monitoring regeneration in the openings

It is critical to monitor the regeneration for stocking, growth, and competition problems. Successful development of oaks, hickories, and other mid-tolerant species depends on establishing sufficient natural or artificial regeneration and keeping it free from competition. These group openings will probably need vegetation management treatments during the early phases.

Vegetation management in the openings

As with the shelterwood treatments, competition control in the group openings is important to keep the desired regeneration both vigorous and dominant. Early and persistent control of competition is better than allowing the competition to overtop the regeneration. Both herbicide and cutting treatments can be used to control competing vegetation in the group openings (**Section 8.1**).

Thinning the regenerated saplings in the openings

A precommercial crop-tree release is an option for saplings growing in openings created earlier. A full crown release should be applied to obtain a maximum of 125 to 185 crop trees per hectare when saplings reach 7.6 m in height, approximately 9 to 15 years following the creation of the opening (Miller *et al.* 1998).

Planting group openings

Seedlings and/or seeds can be planted in the group openings when the likelihood of obtaining sufficient natural regeneration is uncertain, or when landowners have sufficient financial resources to reduce risk of regeneration failure.

Subsequent group opening treatments

It is also important to monitor the development of crown closure in the overstory within the portions of the stand around the group openings. The edges of older group openings may need to be expanded to maintain the growth of seedlings. This can be done during the next cutting cycle or may require intervention before the end of the cutting cycle in order to release the regeneration. These treatments are designed to enlarge the openings and should concentrate on removing suppressed and poor quality trees adjacent to the openings.

Suggested modifications for unique stand conditions

Management of oak regeneration in areas with high deer density

High numbers of deer and/or other herbivores can substantially reduce available acorns for regeneration and may consume or debark regenerating oak seedlings and saplings. Although oaks are well adapted to survive decapitation and can resprout, constant browsing pressure can reduce vigor and regeneration potential by favoring other less palatable species.

The Northeastern Forest Experiment Station in West Virginia has used tree shelters to protect planted and natural seedlings within group openings. Miller *et al.* (1998) state that the shelters have significantly improved seedling establishment by increasing both survival and rate of growth. As well as providing protection from deer browsing, tree shelters also provide an enhanced microclimate that promotes faster growth (relative to other less desirable vegetation) thereby minimizing the potential for competition for sunlight, moisture and nutrients that often occurs when oak seedlings are planted without tree shelters. If protection from deer browsing is the objective, the 1.8 m tall shelter size should be used. Subsequent crown release and competition control may be required six or seven years after planting when the trees have grown out of shelters.

Tree shelters are not recommended when using the uniform shelterwood silviculture system to regenerate oak stands. In this situation, the planted oak seedlings (up to a maximum of 125 superior quality red oak nursery stock per hectare) can be more inexpensively protected from deer browsing by using mesh shelters (e.g., the Texguard mesh shelter). Recent research in southern Ontario (Wagner *et al.* 1995) has found that the tree shelters provided no increased growth advantage in shaded canopy conditions (e.g., the 60 % canopy cover of a shelterwood overstory) as compared to seedlings protected only with mesh shelters.

Another option is to decapitate young oak (i.e., cut off the stem at ground level) already present in the stand or group opening and then protect the remaining stubs with mesh tree protectors or tree shelters to promote vigorous growth of the resprouts.

6.3 LOWLAND HARDWOODS AND SWAMPS

by Ken Elliott, Silvia Strobl and David Bland


M. Patrikeev

Introduction

The dominant tree species in the lowland hardwood forests of southern Ontario are silver maple, red maple (and the red maple X silver maple cross known as Freeman maple), green (red) ash, black ash, white elm, yellow birch, and Manitoba maple. Other associates include eastern cottonwood, large tooth aspen, trembling aspen, balsam poplar, basswood, white birch, white cedar, balsam fir, hemlock, red elm, black maple, sugar maple, butternut, white pine, white ash, and bur oak.

Additional species found in some stands in southwestern Ontario include northern hackberry, swamp white oak, Shumard oak, pin oak, black walnut, honey locust, sycamore, black gum, pumpkin ash[1], blue ash, and black willow. Because some of these deciduous species are uncommon and often rare, the protection of their habitat and use of silvicultural methods that ensure their self-perpetuation should be priorities for management.

Fresh-moist sugar maple deciduous forest ecosite (FOD6)

This ecosite represents the transition between wetland swamp communities (i.e., moist moisture regime) and terrestrial communities (i.e., fresh moisture regime).

This ecosite is found on sands, loams, and rarely on clays. Soils may have an accumulation of organic material from 20 to 40 cm deep. Soil depth ranges from very shallow to deep. This ecosite is found on middle to lower slopes, bottomlands, and poorly drained tablelands with complex micro-topography.

On bottomlands, associated species that must compete well in most soils include white elm, yellow birch, red and black maple, and green ash. With disturbance, green ash, white elm, and yellow birch can become more dominant because they are intermediate in shade tolerance and can outgrow the maples. Without disturbance, a mixed maple stand is likely to result on these sites.

On fertile, abandoned agricultural land, white ash is often a pioneer species, growing rapidly on moist sites. White elm and green ash are common associates on these sites and both do well in moist soil conditions. Sugar and/or red maple can invade these early successional ash stands, and over time become a codominant species.

Basswood is a common associate on upland sites with soils of higher pH. This species grows well in alkaline conditions, and is found on the Canadian Shield, often where marble is the underlying bedrock. It is also common on the shallow soils of limestone plains, where it grows to a much larger size than the associated maple. Logging tends to increase the basswood component of a stand.

[1] This species was first reported by Waldron *et al.* 1996 as occurring in the southwestern counties of Essex, Kent, Elgin and Haldimand-Norfolk.

The ELC describes five fresh-moist sugar maple deciduous forest types: sugar maple-lowland ash; sugar maple-black maple; sugar maple-yellow birch; sugar maple-white elm; and sugar maple-hardwood (Lee *et al.* 1998). The fresh-moist sugar maple-black maple deciduous forest type is considered rare in southern Ontario.

Dominant Trees	sugar maple and several other codominants or common associates including green ash, black ash, red maple, white elm, basswood, yellow birch, and beech
Associates	in Site Region 7E, additional associates include sassafras, hackberry, and to a lesser extent, sycamore, tulip tree, pignut hickory
Common Shrubs	white elderberry, choke cherry, dwarf raspberry; spicebush in Site Region 7E
Common Herbs and Ferns	sensitive fern, spotted touch-me-not, ostrich fern, fowl manna grass, skunk cabbage, marsh fern, trilliums, Jack-in-the-pulpit
Soil Moisture Regime	fresh (MR 2,3) to moist (MR 4-6)
Soil Drainage	imperfect (DR 5) to poor (DR 6)

Fresh-moist lowland deciduous forest ecosite (FOD7)

This ecosite is found on coarse and fine loams and occasionally sands and clays; all soils have fine silt and clay components. Soil moisture regime ranges from fresh to moist (MR 2-6); soil drainage ranges from well (DR 3) to poor drained (DR 6). It is most commonly situated on floodplains, but also on lower slopes and bottomlands, often where deposition due to flooding occurs, but soils can dry out by mid- to late summer (Lee *et al.* 1998). Canopy closure is more open (i.e., it may be less than 60 %), particularly if the stand is dominated by black walnut, white elm, or black willow.

The ELC describes five fresh-moist lowland deciduous forest types for this ecosite: white elm; ash; willow; black walnut; and black maple (Lee *et al.* 1998). The black walnut and black maple forest types are relatively uncommon.

Dominant Trees	white elm, willows, black maple (mainly Site Region 7E), basswood, green ash, black ash, black walnut (Site Region 7E) dominate separately or in variable mixtures
Associates	red maple, sugar maple, white birch, blue beech, butternut, hackberry (mainly Site Region 7E), sycamore (Site Region 7E), blue ash (Site Region 7E)
Common Shrubs	alternate-leaved dogwood, prickly gooseberry; greater presence of vines including Virginia creeper, poison ivy, wild grape
Common Herbs and Ferns	sensitive fern, foamflower, spotted touch-me-not, wild leek, blue cohosh, jack-in-the-pulpit
Soil Moisture Regime	fresh (MR 2,3) to moist (MR 4-6)
Soil Drainage	well (DR 3) to poor (DR 6)

Fresh-moist oak-maple-hickory deciduous forest ecosite (FOD9)

This ecosite represents the transition area between forest and swamp and characteristically supports a mixture of both wetland and terrestrial plant species. It is found almost exclusively in Site Region 7E.

This ecosite usually occurs on soils with finer textures (e.g., loam and clay soils) having moisture regimes ranging from fresh (MR 2,3) to moist (MR 4-5) and drainage classes ranging from imperfect (DR 5) to poor (DR 6,7). It is found on lower slopes, seepage areas, bottomlands and tablelands with poor drainage and complex micro-topography. The water table is often high.

The ELC describes five fresh-moist oak-maple-hickory deciduous forest types for this ecosite: oak-sugar maple; oak-maple; bur oak; shagbark hickory; and bitternut hickory (Lee *et al.* 1998).

The following ecosites have yet to be fully described by the ELC for southern Ontario.

Dominant Trees	red oak, bur oak, sugar maple, red maple, shagbark hickory, and bitternut hickory dominate separately or in variable mixtures
Common Herbs and Ferns	trilliums, violets, jack-in-the-pulpit, wild geranium, sensitive fern, spotted touch-me-not; high sedge and fern diversity
Soil Moisture Regime	fresh (MR 2,3) to moist (MR 4-6)
Soil Drainage	imperfect (DR 5) to poor (DR 6,7)

Maple mineral mixed swamp ecosite (SWM2)

This ecosite consists of red maple or swamp maple, with hemlock, balsam fir, white pine, tamarack, white birch, yellow birch, balsam poplar, and trembling aspen. Dominant species vary. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where flooding duration is short; the substrate is aerated by early to mid-summer. The ELC describes two mixed swamp types.

Birch-poplar mineral mixed swamp ecosite (SWM3)

This ecosite is comprised of white birch, yellow birch, trembling aspen, balsam poplar, with hemlock, balsam fir, and white pine. Dominant species vary. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where flooding duration is short; the substrate is aerated by early to mid-summer. The ELC describes two mixed swamp types.

Maple organic mixed swamp ecosite (SWM5)

This ecosite is comprised of red maple, swamp maple, with hemlock, balsam fir, white pine, and/or tamarack. Substrates are described by the OIP manual (1985) as organic (Of, Om, and Oh). The ELC describes two organic mixed swamp types.

Birch-poplar organic mixed swamp ecosite (SWM6)

This ecosite is comprised of yellow birch, white birch, trembling aspen, balsam poplar, with hemlock, balsam fir, white pine, and/or tamarack. Substrates are described by the OIP manual (1985) as organic (Of, Om, and Oh). The ELC describes two organic mixed swamp types.

Oak mineral deciduous swamp ecosite (SWD1)

This ecosite consists of swamp white oak, bur oak, pin oak, Shumard's oak, with shagbark hickory, big shellbark hickory, bitternut hickory, green (red) ash, red maple, swamp maple, and/or white elm. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where flooding duration is short; the substrate is aerated by early to mid-summer. The ELC describes four swamp types.

Ash mineral deciduous swamp ecosite (SWD2)

Dominant tree species in this ecosite include black ash and green (red) ash, with red maple, swamp maple, silver maple, and white elm. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where flooding duration is short; the substrate is aerated by early to mid-summer. The ELC describes two swamp types.

Maple mineral deciduous swamp ecosite (SWD3)

Dominant tree species in this ecosite are red maple, silver maple, swamp maple, and Manitoba maple. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where flooding duration is short; the substrate is aerated by early to mid-summer. The ELC describes four swamp types.

Mineral deciduous swamp ecosite (SWD4)

This ecosite is found on similar site conditions as the maple mineral deciduous swamp ecosite described above, but it is comprised of less common associates including willows, white elm, white birch, aspen, and yellow birch. It is especially common on floodplains. The ELC describes four swamp types for this ecosite.

Ash organic deciduous swamp ecosite (SWD5)

Black ash predominates on this ecosite. Substrates are described by the OIP manual (1985) as organic (Of, Om, and Oh). The ELC describes one swamp type for this ecosite.

Maple organic deciduous swamp ecosite (SWD6)

This ecosite is comprised of red maple, silver maple, and/or swamp maple. It is found on the same organic substrates as described for the ash organic deciduous swamp ecosite. The ELC describes three swamp types for this ecosite.

Birch-poplar organic deciduous swamp ecosite (SWD7)

This ecosite is comprised of white birch, yellow birch, trembling aspen, and balsam poplar and is found on organic substrates (Of, Om, and Oh). The ELC describes two swamp types for this ecosite.

Changes since the presettlement era

A recent study (Cho and Boerner 1995) in a poorly drained bottomland forest in Ohio investigated patterns of establishment, suppression, and release by examining increment cores of major tree species over time. The researchers found that all sampled trees, despite being scattered throughout the stand, showed similar patterns of establishment and final release from suppression, indicating that relatively large disturbances were important in these poorly drained areas. This finding contrasted substantially with results from an adjacent well-drained upland area where there was little similarity in patterns of establishment and release, suggesting that mostly small canopy gaps caused by treefalls had largely affected canopy dynamics.

Another study in a southwestern Indiana (McCune *et al*. 1988) found greater similarity among tree species composition in the canopy and understory of a lowland forest than in the canopy and understory of an adjacent upland forest tract. By comparison, the lowland forest had:

- a more open canopy because it was broken by ephemeral stream courses and standing water
- faster canopy turnover rates. Wind-killed trees were 74 % more frequent (i.e., 5.9 vs. 3.4 trees/ha/decade), presumably because windthrow of shallow-rooted trees in the waterlogged bottomland soils occurred more often. There was also a 23 % higher overall mortality rate (i.e., 20.0 vs. 16.2 trees/ha/decade).
- less evidence of past cutting; no stumps were observed in the sample plots located in the lowland forest

These findings, as well as an understanding of the autecology of lowland hardwood species (e.g., most species are relatively shade intolerant) suggest that lowland hardwood forests require larger openings to regenerate once advanced regeneration is established.

Successional trends in swamps are less well understood. For red maple swamps one possibility is that these areas were in softwoods such as hemlock, fir, cedar or spruce. Heavy cutting and clearing for agriculture (wet meadows) have eliminated the softwoods (DeGraaf *et al*. 1992).

Choosing an appropriate silvicultural system

The selection of the most appropriate silvicultural system for the management of lowland hardwood forests is based on several factors:

- an understanding of the autecology of the desired species
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed in the following.

Autecology of lowland hardwood species

An understanding of the autecology of desired species is required to make most silvicultural decisions. **Table 6.3.1** summarizes important autecological characteristics for the most common tree species of this forest cover type. For other species not included in this table, see **Appendix B**. The following summary (adapted from Boysen 1994) provides more information on the autecology of silver maple.

Reproduction and early growth of silver maple

a) *Seeds and germination*

- Silver maple is a prolific seed producer.
- Good seed crops are produced every one to two years.
- Seed dispersal occurs in the spring and has an effective range of only 100 m.
- Seeds can germinate in a wide variety of seedbeds and require very little sunlight, but shading from dense overstory can depress first-year germination.
- For seedlings to survive, they must be released from under a closed canopy. Seedlings will only survive for one or two years under dense shade. Similarly, red ash and American elm do not survive for more than one to two years under dense shade.

b) *Site factors*

- Recruitment of silver maple seedlings depends on site conditions.
- Since most silver maple sites are seasonally flooded, it is critical for seeds to land on suitable seedbeds above the water line.
- Silver maple seedling establishment occurs in relatively drier springs in the Simcoe area (R. Lambert, OMNR personal communication, 1995), whereas it will occur on raised organic hummocks (e.g., old stumps, logs, windthrows) in the Cornwall area (G. Velema, Domtar Inc., personal communication, 1995).
- Silver maple grows best on calcareous muck soils superimposed on sand over impervious clay or bedrock, with a pH of about 7.0. It also occurs on wet sands and silt loams (Larsson 1982); Taylor and Jones (1986) described maximum site index values of up to 30.0 meters (SI = 50 years) in Site Region 7E on silty soils, with distinct mottles at between 15 and 30 cm.

c) *Early growth*

- Silver maple is a fast growing tree in both pure and mixed stands.
- Its tolerance to shade ranges from moderately tolerant to very intolerant, depending on the site quality. It is considered to be tolerant on good sites (with relatively short periods of flooding) to almost intolerant on poorer sites.

d) *Competition*

- Silver maple seedlings are highly intolerant of competing vegetation (Burns and Honkala 1990*a*). Therefore regeneration from stump sprouts is seen to be an effective and inexpensive regeneration option.

- Seedlings of species with less proportionate root biomass (e.g., American sycamore) are most adversely affected by root competition from invading tree roots than are species which accumulate a greater proportion of total dry mass in roots (e.g., red maple). It is possible that greater partitioning of total dry mass to roots results in more absorptive power per unit of shoot and greater buffering against low soil water or nutrient availability (Jones *et al*. 1989).

e) *Sprouting*

- Most species in the lowland hardwood forest[3] are prolific sprouters; trees that are 20 to 25 cm DBH or less will produce the greatest number of stump sprouts.
- Both red and silver maple have the ability to develop fully stocked stands from stump sprouts.
- Stumps of about 25 cm DBH and stumps of formerly fast growing trees sprout most prolifically from both the root collar and the lower stem (von Althen 1990). Note however, that most silvicultural, timber, and wildlife objectives are not met until large diameters (e.g., 50 cm +) are attained and that most successful regeneration is the combined result of stump sprouts, advanced seedlings, and new seedlings. By allowing stands to develop large-crowned dominants, abundant, high quality seeds become available and there may still be stems that are good sprouters.

Reaction to competition

- Due to their high moisture content and rich soils, lowland sites often have problems with heavy competition from shrubs such as raspberries, grasses, and large wetland plants (e.g., cattails). Competition problems should be carefully evaluated prior to silvicultural decision making. For example, clearcutting on very poorly-drained soils without adequate advanced regeneration or in potential frost pockets may result in an overabundance of herbaceous or shrubby vegetation (Leak *et al*. 1986).

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[3]For example, stumps of freshly cut seedlings and sapling white ash sprout readily with only one or two stems being produced (Burns and Honkala 1990*a*). Even though basswood produces the heaviest and most frequent seed crops of Ontario's hardwoods, trees rarely originate from seedlings in forested conditions. Instead basswood is a prolific sprouter, with sprouts developing from dormant buds on stumps of all sizes, but more abundantly from stumps of sawlog-sized trees. It can also sprout well from stumps of healthy trees cut at ages of up to 100 years and with a DBH as large as 70 cm (Stroempl 1983). White elm and bur oak also have a high frequency of sprouting (Stroempl 1983).

Table 6.3.1: Autecology of common species in the lowland hardwood forest cover type (Burns and Honkala 1990*a* and 1990*b*).

Species	Silver maple	Red maple	Red/green ash	Black ash	White elm	Hemlock	Yellow birch
Site	Rich, moist bottomlands	Wide range of soils and sites	Fertile, moist, well-drained soils	Poorly-drained, peat, muck soils	Rich, well-drained loams	Moist soils with good drainage	Well-drained, fertile loams, moderately drained sandy loams
Canopy openings to secure regeneration/ growth	Variety	Variety	Variety	Openings	Openings or clearings	Uniform canopy (70%) or single-tree	Tree height group or uniform canopy (60%)
Seed periodicity	1 year	1-2 years	1 year	1-8 years	1 year	2-3 years	1-4 years
Seedbed type	Moist, mineral soil-organic mix	Mineral soil	Humus, mineral soil	Mineral soil	Mineral soil, decaying wood, humus	Mineral-humus mix, burned duff, decaying wood	Mineral soil, humus
Sprouting ability	Good	Very good	Very good	Very good	Very good	Very poor	Poor
Likelihood of advanced regeneration	High	Moderate-high	High	Low	High	Moderate-high	Low
Shade tolerance	Tolerant to intermediate; seedlings are intolerant	Tolerant (decreases with age)	Tolerant (decreases with age)	Intolerant	Intermediate	Very tolerant	Intermediate
Tending need	Crop tree	Competition	Crop tree	Competition	Competition	Seedbed	Crop tree
Self-pruning	Good	Good	Good	No data	Good	Poor	Good
Response to release	Very good	Very good	Good	No data	No data	Very good (dieback, if excessive)	Moderate (dieback, if excessive)
Rot/stain defect	High	High	Low	High	Moderate-high	Low	High
Bole/form defect	Fork	Fork	Fork, epicormics	No data	Fork	Shake	Fork
Decline hazard	Moderate	High	Low (premature defoliation)	High	High (insect, disease)	Moderate-high	Moderate-high
Growth rate	Fast	Fast-moderate	Fast (decreases with age)	Slow	Fast	Slow	Moderate
Wildlife values	Mature forest cover, cavity nest sites, food source for squirrels, beaver, upland gamebirds	Wildlife browse	Wildlife browse	Deer browse, food for beaver	Food for game birds, small mammals	Winter wildlife cover, browse	Catkins, raptor nesting sites

Table 6.3.1: *continued*

Species	Trembling aspen	Balsam poplar	Large-tooth aspen	Basswood	White birch	White cedar	Balsam fir
Site	Most site types; shallow, rocky to deep loam sands, clay	Fresh to moderately wet soils (associated with river flood plains)	Moist, fertile, sands, loamy sands	Moderately moist, sandy loams-silt loams	Most site types; prefers well-drained, sandy loams	Wide variety of moist, organic, mineral soils	Moist, well-drained inorganic, organic soils
Canopy openings to secure regeneration/growth	Clearings (2X tree height group or larger)	Clearings (2X tree height group or larger openings)	Clearings	Tree height group or uniform canopy (50%)	Fire or other clearings	Small clearings	No data
Seed periodicity	4-5 years	1 year	2-3 years	1-2 years	2 years	2-5 years	2-4 years
Seedbed type	Mineral soil, humus	Mineral soil	Bare, moist mineral soil	Mineral soil, humus mix	Mineral soil, humus, decaying wood	Decaying wood, mineral soil, humus, sphagnum mosses, burned organic soils	Mineral soil, decayed wood, burned duff, pioneer mosses
Sprouting ability	Excellent (root suckers)	Very good	Excellent	Very good	Good	Good (layering)	Good (layering)
Likelihood of advance regeneration	None	None	None	Moderate	None	High	High
Shade tolerance	Intolerant	Intolerant	Intolerant	Intermediate-tolerant (increases with age)	Intolerant	Tolerant	Very tolerant
Tending need	Competition	Competition	Competition	Crop tree	Self-thinning	Adequate moisture; seedbed preparation	Competition
Self-pruning	Good	Good	Good	Very good	Good	Good	No data
Response to release	Good, if done early enough	No data	Good, if done early enough	Good (dominant, codominant crown classes only)	Good	Good at all ages	Good
Rot/stain defect	High	Low	High	Moderate	High (red-heart, cambium miners)	High	High (red heart fungus)
Bole/form defect	Hypoxylon canker	Cankers, distortion from frost damage	Hypoxylon canker	Sweep	Stem cankers	Curved butt, poor form in larger trees	Broomed shoots
Decline hazard	Moderate-high	No data	Moderate-high	Moderate	Moderate-high	No data	High (spruce budworm)
Growth rate	Fast	Fast	Fast (declines with age)	Moderate-fast	Fast (declines with age)	Slow-moderate	Moderate-fast
Wildlife values	Nesting cover, winter food source	Wildlife browse, buds provide food for ruffed grouse	Wildlife cover, spring-summer food source for ruffed grouse, winter food source for beaver, moose	Mast, wildlife browse, bee/honey	Cover, browse for deer, moose; catkins, buds food source for ruffed grouse; seeds food source for other birds	Wildlife cover, deer yard, browse, mast	Wildlife cover, browse, winter food source for game birds

Factors limiting growth and development

- *Inundation:* Potted seedlings of red maple, American sycamore, and American elm that were grown in deeply shaded forest environments and subjected to inundation (i.e., flooding of the entire stem for several days early in the growing season followed by well drained conditions for the remainder of the experiment) had high mortality and substantially reduced growth. Red maple had higher survival (89.5 % vs. 38.3 % for American elm) than any other species (Jones *et al*. 1989).
- *Flooding:* Constant water-logging of the soil of potted seedlings of red maple, American sycamore, and American elm resulted in no mortality and minor or no growth reduction (Jones *et al*. 1989). In this study pots were placed in a plastic-lined concrete channel and watered daily from above resulting in continuous soil saturation without inundation. Later life stages of these species are probably more tolerant of flooding than are current year seedlings.
- *Shallow rooting habit:* The shallow rooting system of many lowland hardwood species makes them vulnerable to windthrow, a concern in partially cut stands with numerous edges. Shallow roots are also vulnerable to trampling and damage from skidding and drought.
- *Shading:* Saplings of silver maple and many other lowland hardwood species rarely exhibit tolerance to suppression and require a single large disturbance to enter the canopy (Cho and Boerner 1995).
- *Insects:* Few major insect problems occur in natural lowland hardwood stands.
- *Disease:* Few disease problems occur in natural lowland hardwood stands, but Dutch elm disease has substantially influenced the composition of such stands by removing a formerly vigorous white elm component.
- *Browsing by beaver:* Feeding preferences of beaver can influence the composition, density, and successional patterns of lowland hardwood forests. For example, a study of six beaver colonies on the banks of the lower Chippewa River in west-central Wisconsin (Barnes and Dibble 1988) found that beavers were selective in their choice of woody plants, preferring ash and bitternut hickory over other species. Beaver cutting substantially reduced tree density and also had a significant effect on the predicted tree composition of the study sites. A major reduction in future density is predicted for ash, hickory, and hackberry in areas of beaver activity, with a concomitant increase in the density of basswood and elm. Silver maple, which appeared to be disliked by beavers, and prickly ash, which forms dense thickets in areas opened by beavers, could also increase in density (Barnes and Dibble 1988).

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand should be managed to provide other values such as wildlife habitat.

In southern Ontario, many attempts at intensive forest management of lowland hardwood stands have had poor results, mainly due to rising water levels, die-back/decline, and poor timing and choice of equipment. Site evaluation is a critical first step to silvicultural decision making for lowland hardwood forests. The level of the water table is particularly important since it affects the rooting depth of trees on the site. High water table levels result in shallow rooting and trees that are more prone to windthrow. Sites with high or potentially high water tables or shallow rooting depths with poor drainage should be carefully evaluated before any silvicultural activity is proposed. Often such sites should be designated as protection forests that provide important water quality/quantity protection services and wildlife habitat. The impacts of all proposed silvicultural operations on the local hydrology and wildlife habitat should be assessed before any activity is implemented.

If the answer to any of the questions listed in **Box 6.3.1** is “yes”, the stand should be left alone (i.e., no silvicultural activities should be considered). Failing this, harvesting operations should be restricted to the cutting of fuelwood only on frozen ground, and no more than one-fifth of the basal area of the stand should be removed at any one time.

Box 6.3.1: Questions that managers should ask before considering silvicultural options for lowland hardwood stands or swamps.

- Will harvesting cause a significant rise (e.g., at least 15 cm) in the water table? The answer to this question may require an evaluation of the risk of flooding caused by beavers or seasonal inundation by adjacent water bodies.
- Is the site very wet (i.e., moisture regime of 7)?
- Is the dominant forest shallow rooted (i.e., most roots are within 30 cm of the soil surface)?
- Is the site unproductive (i.e., a site index of less than 20 m at 50 years)?
- Does the forest provide habitat for vulnerable, threatened, or endangered species or significant wildlife habitat that would be adversely affected by harvesting activities?
- Is the site considered a provincially significant wetland or ANSI?

Careful silvicultural intervention may be possible provided that the answer to each of the above questions was “no”. If activities can be carried out on a given lowland site, they should only be done in the winter months after sufficient cold weather and snow will permit the creation of stable ice roads. The site damage caused by poor decisions regarding management and operations can far outweigh any silvicultural improvement to growing space or light conditions.

Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands. Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Most lowland hardwood stands have a history of high-grading and many have been degraded by past “logger’s choice” harvesting operations. Such operations may have left both the residual stems and the site in poor overall condition.

Wildlife habitat and other natural heritage values

Lowland hardwood forests often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Lowland hardwood stands are important to wildlife and total species diversity may be considerably higher than in adjacent areas due to the variety of vegetation communities (e.g., wetland and terrestrial communities) that may be present. Plant diversity in particular is frequently richer than in upland hardwood forests because of higher levels of sunlight and often more fertile, organic soils.

Lowland hardwoods are frequently less attractive to many people due mainly to poor access because of areas of standing water and saturated soils, and concentrations of biting flies. This reduction in human use and activity in these stands often results in relatively less disturbance for wildlife while an abundance of food and nesting and denning sites attract many animals. Some of these stands support species of conservation concern such as the red-shouldered hawk and prothonotary warbler, two birds that do not tolerate human disturbance well.

Many of the birds found here nest in tree cavities. Two tree species are particularly important. Silver maple and sycamore have a tendency to develop larger cavities and hollows that provide nests for many bigger birds including woodpeckers, owls, and wood ducks, and dens for raccoons, squirrels, and opossum. A large tree may also provide important winter shelter for several tree-climbing mammals.

Many trees of lowland hardwood forests provide valuable wildlife food. For example, acorns of pin oak and swamp white oak are important food for migrating waterfowl, especially mallards and wood ducks. Wild turkeys, woodpeckers, squirrels, and white-tailed deer are other prominent consumers. Red maple (twigs, foliage, and sprouts) is a preferred food for white-tailed deer, snowshoe hares, rabbits and beavers. Evening grosbeaks, finches, and songbirds and gamebirds, squirrels and chipmunks eat the seeds. Manitoba maple seeds are eaten by squirrels, and evening grosbeak, purple finch, many other bird species. Beaver eat the bark. Yellow birch saplings are a favorite browse of white-tailed deer and the seed catkins, which often remain on the tree, provide an important food resource for resident birds. Numerous other species that can be found in these stands such as hackberry, black gum, white elm, hickories, and willows provide food for a variety of birds and mammals.

Where the potential for management for forest products is limited (i.e., due to site conditions, presence of rare species), landowners and managers might consider silvicultural prescriptions that primarily encourage the development of wildlife habitat, particularly cavity and denning trees and mast-producing trees. For example, many of these stands are found in bottomland and wetland areas where local wood ducks populations could expand if more nesting habitat were available. In a study at the Muscatatuck National Wildlife Refuge in southcentral Indiana (Robb and Bookhout 1995), the density of suitable cavities for wood ducks was highest in areas with mature or sawlog trees (1.69 cavities/ha) than in areas with smaller trees (0.31 cavities/tree). This finding suggests that in bottomland forests, trees should be grown for longer rotations to provide more nesting habitat.

Another study (Kowal and Husband 1996) described characteristics of trees most often used by cavity-nesting birds. These included dead trees with broken tops and with more than 80 % of the bark still on the tree, as well as trees with low resistance to heartwood decay and ice damage. Since trees with these characteristics pose little or no competition to crop trees, they should be left standing wherever they do not pose a safety hazard.

Sometimes these stands support rare, locally uncommon, and/or declining tree species, especially in southwestern Ontario. These trees should be identified and protected. Silvicultural activities and forest operations in general that are conducted in the stand should not result in the degradation or loss of the site conditions required by these species.

Other considerations

Where harvesting is used to achieve silvicultural objectives, a careful economic analysis should be done first to determine whether silvicultural treatments are worthwhile.
Some harvesting operations in lowland hardwood forests are conducted to achieve non-commercial objectives (e.g., cutting fuelwood for personal use, wildlife habitat improvement), and many operations are barely profitable due to low product values and increased harvesting costs. Often the only way to ensure a sizeable profit is to remove all the most valuable trees, as has been done in the past by high-grading.

Landowners and managers will want to consider the overall return on the investment. For example, silver maple may be worth less on a board foot basis than other trees such as red oak, black cherry, and sugar maple. However the relatively rapid growth rate of silver maple can give it comparable value.

Other key considerations are the depth of the water table and the rooting depth because they affect stand sensitivity to numerous silvicultural operations. Therefore before any silvicultural management is even proposed, sites with high or potentially high water table levels, shallow rooting depths, or poor drainage should be carefully evaluated. Often stands on these sites will be designated as protection forests, set aside to provide wildlife habitat and retention of important hydrological functions. The impacts of potential silvicultural activities on fish and wildlife habitat should be evaluated.

Silvicultural activities conducted on lowland sites should be restricted to the winter months when sufficient cold weather has frozen the ground, permitting the creation of stable ice roads. This is important because the benefits provided by silvicultural activities (e.g., improved growing space, increase sunlight) can be negated by serious site damage.

Recommended silvicultural systems for lowland hardwoods

Table 6.3.2 presents an overview of stand conditions and management objectives that can influence the choice of a silvicultural system for use in lowland hardwood forests. Two silvicultural systems are most appropriate for managing lowland hardwoods: uniform shelterwood and group selection. With either system, managers must always try to prevent forest activities from adversely affecting the water table and disrupting local patterns of drainage. The site must not be allowed to become saturated for extended periods during the growing season. Encouraging regeneration with both systems is discussed below.

With both systems managers will essentially be managing even-aged stands (i.e., with group selection, small areas of group openings located throughout the stand are even-aged). Therefore thinning and crop-tree selection will be important components of stand management until regeneration treatments are required. Results from a thinning experiment in a silver maple stand in southwestern Ontario demonstrate the increased productivity that can be realized from thinning treatments on appropriate sites. All of the criteria for crop-tree selection discussed in **Section 5.3**, also apply to lowland hardwood forest cover types and are important to ensure that thinning operations lead to improved growth and quality of residual stems.

Staff of Domtar in eastern Ontario manage lowland hardwood forest types according to what they believe were their historical compositions. On fresh sites (MR 1-3), they are trying to restore the all-aged, mixed tolerant hardwood or hemlock forest using group selection. This silvicultural system is preferred on fresh sites with vigorous advanced regeneration of red maple, sugar maple, yellow birch, hemlock, and/or basswood, and sufficient AGS stocking. On wetter sites, they are looking for regeneration options to sustain even-aged lowland hardwood forest types. Presently, they are still thinning most of these stands because of the young age of the trees (M. Streit, Domtar Communication Papers, personal communication, 2000).

Table 6.3.2: Choosing an appropriate silvicultural treatment for lowland hardwood forests in southern Ontario.

	Crop-tree thinning	Regeneration treatments	
		Uniform shelterwood	**Group selection**
Objectives for stand	• produce high quality timber from future commercial harvests	• develop new even-aged lowland hardwood stand	• develop patches of even-aged lowland hardwood regeneration
Soil moisture	• sites should be “drier” (i.e., moisture regime 3-5) • no silvicultural operations should be conducted if moisture regime is 7 or very poorly-drained	• sites should be “drier” (i.e., moisture regime 3-5) • no silvicultural operations should be conducted if moisture regime is 7 or very poorly drained	• no silvicultural operations should be conducted if moisture regime is 7or very poorly-drained
Site productivity	• pre-commercial and commercial thinning are worthwhile only on the more productive sites	• will require high investment in vegetation management on productive sites where competition from shrubs such as raspberries, as well as grasses and large wetland plants (e.g., cattails) can be expected	
Presence of advanced regeneration	• not applicable until regeneration treatments are required	• seedlings of typical lowland hardwood species should be present before the overstory is removed by harvesting	• if seedlings are not present in the planned group openings, trees in the surrounding canopy should be of seed-bearing age, it should be a good seed year, and the group opening should create conditions that stimulate germination
Aesthetic considerations	• produces a more uniformly spaced stand with less diversity of sizes; crop trees will likely have paint on them	• most of the high forest canopy will be lost for a period of time following removal cut(s)	• stand develops patchy appearance and a significant proportion of high forest canopy is always maintained
Wildlife habitat	• see description for “uniform shelterwood”	• avoid implementation in areas where forest interior species (e.g., Acadian flycatcher, prothonatory warbler) may be negatively impacted	• results in the least disturbance to the majority of the mature canopy; important if the stand provides significant interior habitat for forest birds and/or VTE species such as Acadian flycatcher, prothonatory warbler. • best approximates natural disturbance by heavy winds • only a relatively small area of the stand should be treated at any one time (e.g., 10-30 % of the stand is opened in well-spaced group openings)

Crop-tree thinning

In even-aged lowland hardwood stands not yet mature enough to implement a preparatory cut or group opening, thinning can be conducted using a crop-tree approach. Crop-tree thinning considers individual trees as candidates for a final crop and releases their crowns to allow for the development of high value products (Anderson *et al.* 1990).

Response of even-aged lowland hardwood stands to precommercial thinning

Few silvicultural research studies have been conducted in lowland hardwood forests in southern Ontario, but extensive data summary records exist for one site, a silver maple precommercial thinning trial. This study was conducted in an 18-year-old stand, in a private woodlot located in the Beverley Swamp in Millgrove, Wentworth County, Ontario, from 1953-1968 (Larsson and Jaciw 1959). Results from this study suggest that on productive lowland hardwood sites, thinning young even-aged stands can substantially increase the growth of selected crop trees. Observations by Domtar staff on sites where they are doing second thinnings support this research data (M. Streit, Domtar Communication Papers, personal communication, 2000).

The Millgrove silver maple stand was precommercially thinned in 1953 to three intensities: light (11 to 21 % basal area reduction), medium (28 % basal area removed), and heavy (61 to 65 % basal area removed) by each of two methods: mechanical (i.e., cutting) and chemical (i.e., basal spray of 2,4,5-T). Average stand DBH at the time of thinning was 10 to 12 cm.

Data were collected in 1958 and 1963 (i.e., 5 and 10 years after thinning). Trees released by mechanical thinning still grew more rapidly 5 years after treatment than did those trees released by chemical thinning regardless of the DBH class. Trees treated with the girdling and herbicide treatment took longer to die (i.e., only 11 %, 74 %, and 64 % of the trees in the light, medium, and heavy thinning intensity plots respectively, had died by 1957). Chemical release is not recommended.

In this study silver maple responded well to thinning; the average DBH in the heavily thinned plots more than doubled (i.e., from 11.9 cm to 26.9 cm). Less intense thinnings did not increase individual tree diameter growth as much. Volume growth in the heavily thinned plots was from two to five times the volume growth of the unthinned trees of the same diameter-class, and followed the same trends as for DBH and basal area.

Prior to this study it was believed that thinning that removed more than 30 % of the basal area would result in a profuse growth of epicormic branches on the boles of exposed trees. As expected, Larsson and Jaciw (1959) found that the more open-grown trees in heavily thinned plots had more epicormic branches (i.e., 88 % of trees in heavily thinned plots vs. 39 % in lightly thinned plots). Also, the epicormic branches were better developed on trees in the heavily thinned plots as compared to those on trees in the moderately thinned, lightly thinned and control plots (e.g., average length of the largest epicormic branch was 6.5 m for heavily thinned vs. 2.2 m for lightly thinned trees).

Precommercial crop-tree thinning should not exceed a 33 % reduction of basal area. Domtar staff attempt to reduce the occurrence of epicormic branches by thinning to no more than 33 % of basal area and by carefully selecting crop trees that are dominant or codominant (M. Streit, Domtar Communication Papers, personal communication, 2000).

In younger even-aged lowland hardwood stands, crop-tree thinning that eventually produces 125 high quality trees of commercial species per hectare at maturity is also possible (see the silvicultural prescription provided in **Section 6.1**, Management of young hardwood stands to produce high quality sawlogs).

Coppice thinning prescriptions

Coppicing is an important technique for encouraging the regeneration of many of the hardwood species that occur in lowland forests, and should be encouraged during harvesting operations on these sites, regardless of which silviculture system is being employed. Coppice sprouts must be given adequate growing space to develop into sawlog quality stems. Thinnings begun at an early age concentrate growth on selected stems, increasing subsequent growth and quality. The following should guide coppice thinning prescriptions (Stroempl 1983):

- Thin clumps at an early age, preferably before the sprouts reach 20-years-of-age. If not thinned early, sprouts may decay through the advancing rot from dying companion sprouts. Moreover, severe competition among sprouts causes them to lean and become crooked. Leave at most two or three sprouts to a clump, as widely spaced as possible. Sprouts can be thinned as early as five years following harvest and can be thinned at any time of year.
- Favor the best-formed, most widely spaced, low-origin dominant or codominant sprouts with U-type connections between companion sprouts. V-type sprout connections should be treated as a unit, by either leaving them both or by cutting them both. **Figure 6.2.2** illustrates U-type and V-type connections.
- When selecting the best-formed stems in a clump, particular attention should be paid to the branch stubs: their number, size, and degree of healing greatly affect the future quality of the tree.
- Companion sprouts in U-type connections can be temporarily retained to protect the bole of the selected dominant against sunscald and development of epicormic branches.

Note however, that experience in southeastern Ontario has shown that it is not always possible or practical to follow these coppice thinning guidelines when thinning red maple that have originated from coppice. When thinning in a stand consisting entirely of coppice, a marker must periodically separate V-type connections if stand stocking and canopy closure objectives are to be maintained. Domtar Inc. personnel working with clump separation have learned that older stems (e.g., 21- to 50-years-old) can be separated and that rot is reasonably compartmentalized. Also they plan to re-enter stands after 15 years to capture decline and/or mortality (M. Streit, Domtar Inc., personal communication, 2000).

Commercial thinning with use of stocking guides

Commercial thinning is most applicable on more productive lowland hardwoods sites. It can also be used to accomplish other management objectives such as the creation of wildlife habitat, for example, such as promoting the development of large diameter trees for cavity-nesting species. Where markets for small diameter wood exist, first thinnings can be for commercial purposes, and are usually possible when stem diameters average 20 to 25 cm DBH.

Thinning should focus on removing diseased and slow-growing trees. The amount to be thinned should be guided by stocking guides, for example by using one for the dominant hardwood species (**Appendix E**)**.** Alternatively, thinning treatments should leave a minimum 16 to 20 m^2/ha of basal area and should not remove more than 30 % of the stand's basal area. Depending on species and site, or as indicated by the stocking guide, thinning may occur every 7 to 15 years. The stand's basal area will gradually increase as the best trees grow larger following thinning. Managed stands should generally not exceed 28 to 30 m^2/ha of basal area (Elliott *et al.* 2000).

Regeneration treatments

Either uniform shelterwood or group selection are appropriate silvicultural systems for regenerating even-aged lowland hardwood stands once most trees in the stand have reached maturity. Refer to **Table 6.3.2** for guidelines to determine which system is most appropriate.

Regardless of the silvicultural system chosen for regenerating lowland hardwood stands, many factors including poor seed years, poor germination, heavy weed competition, spring droughts, insect problems, and disease, can lead to regeneration failure. Vegetation management to control competing species and/or supplemental planting may be necessary to obtain adequate stocking of advanced regeneration. Managers will need to monitor sites where regeneration cuts (for uniform shelterwood) or group openings (for group selection) have been done to determine whether follow-up treatments will be required. If planting is required, seedlings should be obtained from a seed zone as close as possible to that of the planting site (**Figure 4.1.4**). A decision to control competing vegetation or supplement natural regeneration by planting should be made within two years of implementing a regeneration treatment.

Uniform shelterwood system

Readers should refer to the discussion on uniform shelterwood in **Section 6.1** for specific guidelines.

Group selection system

Readers should refer to the discussion on group selection in **Section 6.1** for specific guidelines. Several of the species listed in **Table 6.1.10** occur in lowland hardwood forest cover types, and this table provides dimensions for the size of openings required to regenerate them.

The size of group opening will depend on the stand area, height of adjacent trees, and if applicable, slope aspect but for most lowland hardwood species will be between 1 and 2 times the height of adjacent trees in diameter, or range from 0.07 to 0.28 ha in size. Work in lowland hardwood stands should be done during the winter when the site is frozen, or during periods of drought where summer operations are possible. However, to maximize stump sprouting potential, dormant season logging is recommended.

Techniques for encouraging and managing coppice growth

Coppice is regeneration derived from vegetative sprouting of either dormant or adventitious buds of cut, killed, or damaged live stems. Regenerating stands from stump sprouts has been described in ancient Egyptian hieroglyphics, and this regeneration method has been used for centuries in Europe, India, Africa, and the Americas (Daniel *et al*. 1979).

Two types of coppice regeneration can occur:

1. Stump sprouts develop from previously-formed but dormant buds on the cut stem. Cutting may stimulate these buds to sprout as plant hormones from buds on the removed stem would have suppressed their development before cutting occurred. Such sprouts are confined to the immediate area around the parent stem.

2. Root suckers develop from newly-formed adventitious buds which arise from callus tissue on the horizontal roots of some species. These buds are sometimes stimulated to sprout following decapitation of the parent stem. Suckers can proliferate throughout the original root zone of the parent tree.

Coppice stands that originate from either stump sprouts or root suckers are comprised of the same genetic material as the original trees and are often referred to as clones. European experience with coppice forests suggest that after several rotations, it is necessary to regenerate the stand by seed because sprouts produced from third or fourth generation coppice are weak and decrepit (Stroempl 1972). Managers in southern Ontario should not exclusively promote hardwood regeneration by coppice.

However, coppice can be efficiently used to augment natural regeneration of several hardwood species including red maple, silver maple, tulip tree, cottonwood, basswood, and red oak. Stroempl (1983) has outlined some harvesting techniques that encourage the production of stump sprouts (and root suckers in applicable species) and these are listed below.

- Only harvest during the dormant season (i.e. from late fall to early spring, before bud break), preferably on frozen soil conditions.
- Stumps should be cut with a saw as low as possible and bark damage should be avoided. The healthiest sprouts will originate from at or below the ground line because sprouts originating from high on the stump are eventually susceptible to decay, wind throw, and snow breakage.
- Re-cut high stumps closer to the ground to encourage more sprouts to develop from below the ground, and to accelerate healing over of small stumps and decomposition of larger

stumps.

- Cut stumps at a slight angle to encourage water to drain quickly from the stump surface.
- Cut all stems from any existing coppice clumps, otherwise the likelihood of decay organisms entering remaining stems through wounds or cut stump surfaces may lead to a greater incidence of decay in future harvests, especially for hardwoods with soft wood. However, for small sawlog thinnings, it may be best to leave some.
- Cut damaged or otherwise unsuitable advanced growth during cleanings to produce desirable seedling-sprouts.

6.4 EARLY SUCCESSIONAL HARDWOODS

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Introduction

Early successional hardwood stands are comprised primarily of fast-growing but short-lived, shade-intolerant deciduous species such as poplars and white birch. In southwestern Ontario sassafras and tulip tree may be locally common. They are often the first trees to invade and dominate severely disturbed sites but typically last for only one generation or rotation. Unless the site is disturbed again (e.g., by intensive cutting, fire, disease outbreaks, or extensive wind damage), they will be replaced by more shade-tolerant species. Early successional hardwood stands are normally even-aged but they can also occur as pockets within larger stands, having established themselves in openings created by windthrown trees, small local fires, tree removal or death.

Species composition depends on site conditions and quality, existing seed sources, and occasionally, prior stand management. In southern Ontario, many young stands of early successional hardwoods, such as those that become established on abandoned agricultural land or marginal sites, are currently unmanaged. In other older stands, tree growth rates have slowed down and some trees are dying.

Dry-fresh white birch-poplar-conifer mixed forest ecosite (FOM5)

Species composition often depends on the presence of a seed source, and competition among species. For example, white birch can grow on almost any type of soil, but it does not compete as well with some associates (e.g., aspens) because it is slower growing. White spruce can become established with poplar, but generally remains in the subcanopy for some time because it is also slower growing. This is an early successional forest that originates following a disturbance.

This ecosite occurs on sand and loam soils, and the ELC describes two forest types. The dry-fresh white birch mixed forest type is quite common on abandoned agricultural land in eastern Ontario (Site Region 6E), but rare in Site Region 7E. The dry-fresh poplar mixed forest type is common throughout Site Region 6E but rare in Site Region 7E.

Common Species	white birch, trembling aspen, large-tooth aspen, balsam fir, white pine, and white spruce
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1-3)

Fresh-moist poplar-white birch mixed forest ecosite (FOM8)

White birch tends to predominate on cooler, wetter sites while trembling aspen tends to predominate on drier, upland sites. Generally this is an early successional, even-aged forest that follows a disturbance.

This ecosite is found on a variety of different soils, primarily on lower slopes, bottomland, and in seepage areas. The ELC describes two forest types for this ecosite. Both the fresh-moist poplar and the fresh-moist white birch mixed forest types are fairly common in Site Region 6E but rare in Site Region 7E.

Dominant Trees	trembling aspen, large-tooth aspen, and white birch
Common Associates	balsam fir, hemlock, and black spruce
Soil Moisture Regime	moist (MR 4-6) to very fresh (MR 3)

Dry-fresh poplar-white birch deciduous forest ecosite (FOD3)

This ecosite represents an early successional stage, often associated with recently or frequently disturbed sites (e.g., heavy cutting, clearing of forest cover).These species are shade-intolerant and relatively short-lived. However, as other more shade-tolerant species invade and regenerate beneath them, the composition of these forests changes, ultimately becoming a later-successional forest comprised of more shade-tolerant species. There may be a high diversity of shrub and herbaceous plant species in the understory. Canopy closure ranges from about 60 to 85 %.

This ecosite is usually found on sands and coarse loams on upper to middle slope or tableland topographic positions. Soils are often quite shallow and droughty.

The ELC describes two forest types for this ecosite. The dry-fresh poplar deciduous forest type is common in Site Region 6E but uncommon in Site Region 7E. The dry-fresh white birch forest type is common in Site Region 6E and rare in Site Region 7E.

Dominant Trees	trembling aspen, large-tooth aspen, and/or white birch
Common Shrubs	maple leaf viburnum and poison ivy
Common Herbs and Ferns	Canada mayflower, Solomon’s seal, and bracken fern
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1-3)
Soil Drainage	rapid (DR 2) to well-drained (DR 3)

Fresh-moist poplar-sassafras deciduous forest ecosite (FOD8)

Stands dominated by sassafras are restricted to southwestern Ontario. This ecosite also represents a young, early successional forest that has followed a major disturbance. Understory shrub and herbaceous plant species richness can be quite high. Canopy closure varies from about 70 to 85 %.

This ecosite is found on sand, coarse and fine loams, and occasionally on clay, on a variety of topographic positions.

The ELC describes two forest types for this ecosite. The fresh-moist poplar deciduous forest type is common in Site Region 6E but infrequently encountered in Site Region 7E. The fresh-moist sassafras deciduous forest type is restricted to southwestern Ontario, only being common in Essex, Kent, Elgin, and Lambton counties.

Dominant Trees	trembling aspen, large-tooth aspen, or sassafras
Soil Moisture Regime	moist (MR 4-6) to fresh (MR 2, 3)
Soil Drainage	well-drained (DR 3) to imperfect (DR 5), and sometimes poor (DR 6)

Other species combinations of early sucessional communities also occur, and may be difficult to classify to existing ELC ecosites, particularly in southwestern Ontario. For example, early successional forests that include green ash, white ash, hawthorns, white pine, white cedar and pin cherry, or stands dominated by any one of these species, except pin cherry. Stands dominated by black walnut or young, regenerating American elm also occur.

Changes since the presettlement era

Large-tooth and trembling aspen probably both flourished in large natural canopy openings created either by wind or fire. Since these species are both prolific seed producers, they probably became established in wind-created openings by natural seeding (Heeney *et al.* 1980). They probably dominated fire-created openings through root suckers, depending on the stock present in the stand. In both Ontario and the Lake states, most large stands of aspen originated from root suckers, following large fires (Heeney *et al.* 1980). This disturbance agent is likely responsible for the origin of many mature to overmature stands (i.e., greater than 150-years-old) in northern Ontario. Very hot fires are required to remove the duff and expose mineral soil so that aspen seed can germinate and establish, and these types of fires were uncommon (Heeney *et al.* 1980).

White birch probably persisted in blowdown areas and burned areas, where it has been found to exhibit rapid growth and excellent utilization of light (Carlton and Bazzaz 1998). Windthrow and burnt sites provide exposed mineral soil necessary for establishment (Safford *et al.* 1990).

In the absence of disturbance, the mature canopy of aspen and white birch stands likely provided suitable shade conditions for the establishment of other hardwoods, white pine, white spruce or white cedar, that probably replaced these short-lived pioneer species on many sites.

Since total forest cover in southern Ontario is now much lower, it is likely that this forest type occupies a smaller land area than it did in presettlement times. It is fairly common in much of eastern Ontario where the clearing of land for agriculture and its later abandonment have lef numerous old fields occupied by these early successional species.

Choosing an appropriate silvicultural system

The selection of the most appropriate silvicultural system is critical for the management of early successional forests and depends on several factors including:

- an understanding of the autecology of the desired species
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed below.

Autecology of trembling and large-tooth aspen (Davidson *et al.* 1988, Heeney *et al.* 1980, Laidly 1990)

Knowledge of the autecological characteristics of early successional species described below is an important prerequisite for the selection and implementation of the most appropriate silvicultural system(s) designed to encourage successful establishment and regeneration of early successional stands. **Table 6.4.1** summarizes important autecological characteristics for the most common tree species of this forest cover type. For other species not included in this table, see **Appendix B.**

Reproduction and early growth

- Most aspen regeneration originates from root sprouts, the majority of which are produced in the first season after stand disturbance. Soil temperature is an important factor controlling sucker formation and 23^{o} C appears to be the optimum temperature. Stand age does not appear to be a factor.
- Harvest of trembling aspen in the winter produces a higher density and stocking of suckers than in the summer, although generally enough suckers are produced to develop a well-stocked stand at either time of the year. To regenerate a fully stocked stand,120 mature parent stems per hectare are needed while 40 parent stems per hectare are required for minimum stocking. This is equivalent to as little as 5 m^2/ha of basal area in the original stand. Generally the regeneration of large-tooth aspen requires a greater parent stem density than for trembling aspen.
- Bare mineral soil that is constantly moist is an ideal seedbed for aspen. Seedlings are very susceptible to fungi, heat, drought, and competing vegetation. Light is a critical factor in the development of seedlings.

Reaction to competition

- Aspen is a very shade-intolerant species.
- High-density stands of suckers rapidly reach crown closure, and can begin to limit diameter growth within five years. Sucker growth rapidly outgrows competition, but seedlings need to be released from competition to survive. Dominance in sucker stands is expressed in seven to 10 years, at which time crop trees can be identified.

- Large-tooth aspen, trembling aspen, and white birch respond well to thinning. Thinning must often be done at an early age to maximize growth because these species are short-lived and grow rapidly.

Factors limiting growth and development

- Over 300 insect species attack aspen; defoliators cause the most damage. The two most important defoliators are the forest tent caterpillar and the large aspen tortrix.
- Other damaging insects include leaf tiers, leaf rollers, leaf miners, and borers.
- At least four categories of fungal diseases attack aspen:
    - *Trunk and butt rots:* Trunk and butt rots are caused by a number of organisms including heart rot (*Phellinus tremulae*), *Fomes igiarius*, *Radulum casearium*, *Pholiota spectablilis* and *Armallaria mellea*. These rots cause serious volume losses and deterioration if stands are left beyond rotation age (Laidly 1990).
    - *Stain:* the mechanism of infection and staining is poorly understood since it appears to occur with or without microorganisms. Stain does heavily impact wood production in aspen (Laidly 1990).
    - *Cankers:* Hypoxylon canker is the most serious disease of the aspens (Laidly 1990).
    - *Leaf diseases:* Leaf and twig blight of aspen is common throughout Ontario on young regeneration, and ink spot periodically causes defoliation.
- Aspen is the preferred food of beaver. Although this mammal can seriously damage the timber value of a stand, it may also create valuable habitat for many other wildlife species.
- Porcupines can cause heavy damage by eating the bark.
- Fire damages or kills aspen because the species has thin bark. Fire damage provides entry points for disease organisms.

The autecology of both aspen species and the other pioneer species that occur in early successional hardwood sites is summarized in **Table 6.4.1** (from Safford *et al.* 1990, Griggs 1990, Beck 1990).

Table 6.4.1. Autecology of early successional hardwood species (Burns and Honkala 1990*a* and *b*).

Species	Large-tooth aspen	Trembling aspen	White birch	Sassafras	Tulip tree
Site	Moist, fertile, sands, loamy sands	Most site types; shallow, rocky to deep loam sands	Most site types; prefers well-drained, sandy loams	Most site types; prefers well-drained sandy loam soils	Well-drained, moist, loose-textured soils
Canopy openings to secure regeneration or growth	Clearings	Clearings	Fire or other clearings	Openings or clearings	Forest gaps
Seed periodicity	2-3 years	4-5 years	2 years	1-2 years	1 year
Seedbed type	Bare, moist mineral soil	Mineral soil, humus	Mineral soil, humus, decaying wood	Moist, rich loamy soil with layer of litter	Humus-mineral soil mix
Sprouting ability	Excellent	Excellent	Good	Good	Good
Likelihood of advanced regeneration	None	None	None	None	Moderate
Shade tolerance	Intolerant	Intolerant	Intolerant	Intolerant	Intolerant
Tending need	Self-thinning	Self-thinning	Self-thinning	Competition	Low at seedling-sapling stage; required at canopy closure
Self-pruning	Good	Good	Good	Good in well stocked stands	Good
Response to release	Good, if done early enough	Good, if done early enough	Good	Poor	Good
Rot/stain defect	High	High	High (red-heart, cambium miners)	Low	Moderate (log quality declines rapidly after cutting)
Bole/form defect	Hypoxylon canker	Hypoxylon canker	Stem cankers	Low	Moderate-high (grapevine a common cause of breakage, stem malformation)
Decline hazard	Moderate-high	Moderate-high	Moderate-high	Foliage diseases common	Low-moderate
Growth rate	Fast (declines with age)	Fast	Fast (declines with age)	Slow-moderate	Fast
Wildlife values	Wildlife cover, spring-summer food source for ruffed grouse, winter food source for beaver, moose; important but short-lived snag and cavity trees	Nesting cover, winter food source; important but short-lived snag and cavity trees	Cover, browse for deer, moose; catkins, buds food source for ruffed grouse; seeds food source for other birds	Browse	Browse

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.

Current stand composition, structure, and condition

Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Early successional forests provide important wildlife habitat. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Davidson *et al.*(1988) provides the following information about the use of early successional hardwood stands by wildlife.

1. Aspen is a fair browse source for deer in summer, and provides some summer shelter (Heinen and Sharik 1990). In some areas it is heavily browsed by deer in winter. In southeastern Ontario, aspen and white birch can provide key moose browse, particularly in summer.
2. Young poplar stands in southeastern Ontario often contain a variety of fruit producing shrubs including blueberries, cherries, raspberries and strawberries all of which can be utilized by black bears. Black bears also feed on swollen aspen buds in the early spring. Aspen foliage is a choice summer food for porcupines.
3. Beaver consume trembling and large-tooth aspen and balsam poplar bark, leaves and branches for food, and branches and twigs are used in dam and lodge construction.
4. Rodents, rabbits and snowshoe hares use poplar stands for food (especially in winter when they gnaw the bark), and the same stands are also used by many of their predators including lynx, fox, wolf, coyote, and weasel.
5. Aspen and white birch snags and decaying live trees are used by cavity-nesting ducks, woodpeckers, and mammals.
6. Staminate buds of aspen, along with catkins of birch, hazel and willow constitute 85 % of the December-March diet of ruffed grouse. Grouse need different age classes of aspen to meet specific needs: sucker stands for brood cover, sapling/polewood stands for adult wintering and nesting cover, and older male aspen to supply winter food and nesting cover (McCaffrey *et al.* 1997). The buds and catkins are a favored food for numerous other birds.
7. 116 species of birds are found in aspen-dominated stands, of which 16 breed in abundance.

Since early successional hardwoods are important to many wildlife species, they could be managed in southern Ontario:

- to diversify local or regional habitat, particularly in areas with little early successional forest or in areas with higher (> 30 %) forest cover
- to provide animal movement corridors by linking fragmented forest patches with larger forested areas. Many old fields are more rapidly reforested and/or restored with early successional species
- to provide buffers or gradual transitions around significant natural areas, especially those surrounded by incompatible land uses in densely settled or agricultural areas
- to increase the amount of forest interior by encouraging establishment of early successional species to fill in irregular edges
- to increase local populations of certain wildlife species that rely on this cover type for some habitat needs (e.g., ruffed grouse)

In southwestern Ontario, some early successional hardwood stands support Carolinian trees such as sassafras and tulip tree. Where these species are locally or regionally rare, they should be retained.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of early successional hardwood stands.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood or clearcut silvicultural systems and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Managing early successional hardwoods

Early successional forests comprised of short-lived pioneer species such as trembling aspen, largetooth aspen, and white birch tend to form even-aged stands. They can be managed by clearcutting, an even-aged silvicultural method designed to mimic sudden, large-scale natural disturbances that result in stand replacement by the same species. Clearcutting is preferred in mature stands of at least 0.5 ha in order to replace them with a new vigorous stand. It may also be used to rejuvenate selected stands that are degraded due to past mismanagement or insect or disease damage.

Although the practice of clearcutting is usually not recommended for use in southern Ontario, it has some merit for periodic application on large sites located in areas where forest fragmentation is not a problem. Well-planned clearcutting can help to create stands of different ages and species composition across the landscape, thereby improving the diversity of wildlife habitat and species in a region. Furthermore, on sites with unfavorable growing conditions for most species (e.g., low available moisture, poor soil drainage, shallow soil), it is often easier to maintain early successional species by using periodic clearcuts.

Two-aged stands can develop when shade-tolerant species such as spruce, fir, tolerant hardwoods, as well as, pine or cedar become established in the understory. Appropriate management can encourage this advanced regeneration and eventual succession to a different forest type that will have greater long-term timber value, provided that the surrounding forest cover, as well as landowner objectives allow it.

Most early successional hardwood stands should probably be managed to encourage replacement by shade-tolerant species (i.e., to simulate natural succession in the absence of a major disturbance event). Provided that seed sources are found in adjacent woodlands, most of these stands in southern Ontario will require little or no intervention and in time, will develop an understory of shade-tolerant hardwoods, primarily dominated by sugar maple and American beech.

Locally or regionally rare, early successional hardwood species such as sassafras and tulip tree should be retained and regenerated. These two species are usually managed within tolerant hardwood stands by the group selection system.

The decision key presented in **Table 6.4.2** can help resource managers select appropriate silvicultural option(s) for early successional hardwood stands. Follow the numbered decision points in the table until a management option (in italics) is reached, that best describes the existing site and stand conditions. Then read the accompanying text description for further details on the management option.

Table 6.4.2: Decision key for early successional hardwood management in southern Ontario.

Text	Decision Factor Description	Continue to Point No.
	Early successional species:	
1.	are dominant (i..e., comprise > 50 % of the canopy) …...	2
1.	are not dominant (i.e., comprise 25-50 % of the canopy)	5
	The stand age is:	
2.	<10 years ……………………………………………………………………	*Wait until tree dominance is established – usually between ages 10 to 40*
	10-40 years ………………………………………………………………	*Thin to maximize growth & yield*
2.	40-80 years ……………………………………………………………………	*Monitor for stand decay or decline*
2.	> 80 years ………………………………………………………………	3
	The landowner's management objective is to:	
3.	maintain an early successional hardwood stand ………………….. ….	*Clearcut*
3.	manage succession to a tolerant hardwood forest cover type……….	4
	Advanced regeneration of tolerant hardwood species:	
4.	exists under the mature early successional species canopy …..……….	*Promote/release regeneration*
4.	is not present under the mature early successional species canopy …...	*Underplant*
	The landowner's management objective is to:	
5.	retain some early successional hardwood species within stand ……...	*Group selection/Shelterwood*
5.	not retain any early successional hardwood species within stand…….	*Single-tree selection*

1. Dominance of early successional species in the stand

To determine appropriate silvicultural options for stands containing early successional hardwoods, this silvicultural guide considers two stand types:

a) Stands with early successional species such as large-tooth aspen, trembling aspen, white birch, and sassafras that dominate (i.e., comprise more than 50 % of the canopy of the stand); and

b) Stands with early successional species such as tulip tree, sassafras, or other species that are minor components (i.e., comprise less than 25-50 % of the canopy of tolerant hardwood stands), and the objective is to increase or maintain their proportion.

Stands in which these species are predominant are best managed with even-aged silvicultural systems, while stands with only a minor component of these intolerant hardwood species can be managed with uneven-aged silvicultural systems.

2. Stand age and thinning to maximize growth and yield

Stand less than 10-years-old

Even-aged stands that are less than 10-years-old should be left alone so that dominance can develop. Once dominance has developed crop trees can be identified.

Stands 10- to 40-years-old

Even-aged stands from 10- to 40-years-old can either be thinned to maximize growth, or they could be left to thin naturally. Normally, thinning operations in early successional hardwood stands are only performed if the cost of thinning can be offset by increased revenue from eventual sales of higher value timber for which there is a local market (Davidson *et al.* 1988). First thinnings are preferably performed on young sapling and polewood stands.

Precommercial thinning in aspen stands accelerates diameter growth of remaining trees and might provide low value forest products (e.g., pulpwood) by removing suppressed or diseased trees. Early work in aspen stands in Ontario found that diameter growth was increased by thinning, height growth was not affected, and rotation lengths to merchantable products were decreased (Davidson *et al.* 1988). Historical data and computer simulation modelling in Minnesota determined that volume production following thinning could be increased by up to 40 % on good quality sites (Perala 1977). Although thinning response rates in southern Ontario will likely differ, they found that growth responses were greatest when thinnings were done at 10-, 20- and 30-years-of-age, reducing stand densities to 2470, 1235 and 617 stems/ha, respectively (Davidson *et al.* 1988). Also good results were achieved with just two thinning operations at age 10 and 30 years, to 1358 and 494 stems/ha, respectively (Davidson *et al.* 1988). Slightly less volume was produced with just two thinnings, and average stem diameter was 5 cm smaller, than when three thinnings were used (Davidson *et al.* 1988). Similar results were found in another study, where thinning was conducted seven years after clearcutting, reducing the stem count from 3750 to 695 stems/ha.

Aspen of 30- to 40 years-of-age also benefits from commercial thinnings. Thinned plots had a volume increase of 7.1 m^3 (17 cords) per hectare higher than uncut plots in stands where diseased and defective trees were removed and the remaining trees were left at a spacing of approximately 4 m by 4 m. After 15.5 growing seasons, veneer value (in 1969 dollars) on uncut plots was $912/ha, and on thinned plots it was $1402. Pulpwood value on uncut plots was $196.50/ha and on thinned plots it was $228/ha (Hubbard 1972). In other studies, thinning to a spacing of 2.5 m or 1600 trees/ha also resulted in a significant growth response (Davidson *et al.* 1988).

When thinning in aspen stands, damage to residual stems must be avoided because aspen are easily infected by disease that can enter through these wounds (Davidson *et al.* 1988).

Generally white birch should respond to thinning in the same manner as aspen mainly because it is also a short-lived, fast-growing species. Thinnings in white birch stands have been shown to increase diameter growth proportionately with the degree of release (Safford *et al.* 1990).

Tulip trees also respond well to release by thinning, and research has shown that young trees can strongly benefit from a four-sided crown release (Johnson *et al.* 1997).

Stand 40 to 80-years-old

Aspen and white birch are relatively short-lived species and consequently their rotation ages are short. Stands that are between 40- to 80-years-old should be monitored for stand decay or decline.

Accumulation of biomass/ha in aspen stands peaks at 30-40 years in southern Ontario (Davidson *et al.* 1988), and biomass production remains at this peak for a further 30 years (i.e., diameter increases but biomass/ha does not). After 70 years, biomass rapidly declines from rot, stain and mortality. For example, the cull rate in aspen stands changes from 10 % at age 30, to 17 % at age 100, and to 35.5 % at age 150 (Davidson *et al.* 1988). Forty years is the rotation age for pulpwood production, and 70-80 years is an appropriate rotation age for sawlogs or veneer aspen. If an aspen stand continues to develop high quality wood past this age however, it could continue to be managed until it started to decline.

White birch matures at about 60 years of age, and responds very little to release after this time (Safford *et al.* 1990). Seventy to 80 years would also appear to be a reasonable rotation age for white birch, although it could be longer if tree health and log quality remained high.

Stand > 80-years-old

Most stands of aspen and white birch are considered over-mature or declining by the time they are 80-years-old. At this stage, landowners should choose among silvicultural options that can either regenerate a stand comprised of similar species or encourage succession to a different stand type (e.g., tolerant hardwood or pine forest).

3. Choosing whether to maintain the early successional species in the stand

The choice of whether or not to maintain early successional species should be made keeping these factors in mind:

- If the stand contains uncommon deciduous tree species such as sassafras or tulip tree, the retention of these species will help to conserve local or regional species diversity.

- Aspen and birch have significant value for wildlife, especially in landscapes where there are few other such stands.
- Market prices for aspen products in southern Ontario are currently low but have improved recently due to new uses for poplar pulp (e.g., medium-density fiber board, oriented-strand board).
- White birch is more valuable than aspen, but less valuable than the tolerant hardwoods.

Regenerating early successional hardwood species to maintain them on sites where their mature canopies are declining will require clearcutting or some modification of this silvicultural system. Specific guidelines vary slightly, depending on the dominant canopy species to be regenerated. These are discussed below for stands dominated by either aspen, white birch or tulip tree. A modification of clearcutting, and other suggested actions to minimize the negative effects associated with clearcuts are also presented in this section.

If the management objectives for the stand are to promote natural succession to a later successional forest cover type such as a tolerant hardwood forest, clearcutting is not an appropriate option.

Aspen

In Ontario, regenerating aspen stands as early successional stands is accomplished by clearcutting. To reproduce a fully stocked aspen stand, 120 parent stems/ha are required, while 40 stems/ha will produce minimally stocked stands. The clearcut system is the only silvicultural system that creates conditions suitable for aspen regeneration (Davidson *et al.* 1988).

Clearcutting removes all trees in the stand, thereby promoting root suckering and providing full light for rapid growth. Any partial clearcut system (e.g., strip cutting) will reduce root suckering and growth, and limit future silvicultural options as re-entering the stand after sprouting will cause significant damage (Schier *et al.* 1985). Both merchantable and non-merchantable trees are generally removed, as residual stems are not conducive to optimum regeneration, growth or development (Davidson *et al.* 1988). Full-tree, or tree-length skidding are the best harvesting methods for promoting aspen regeneration as they destroy shrubs in the understory, and minimize slash accumulation. Harvesting in the winter season when trees are dormant produces a greater number of suckers of higher quality than harvesting in summer (Heeney *et al.* 1980), and a more even distribution of suckers (Bella 1986).

The selection, shelterwood, or partial clearcut systems reduce root suckering and growth and are not generally recommended to regenerate aspen because this species is shade-intolerant (OMNR 1997). The shelterwood system has been suggested for use in Wisconsin however, to regenerate trembling aspen and it appears to provide a potential advantage. Leaving 20-25 residual aspen trees per hectare should reduce the number of suckers produced through plant hormone regulation in the roots. With fewer suckers, more energy and production should be focused on potential crop trees (Ruark 1990). This system is not recommended in areas where mortality from pathogens or disease is anticipated to be high (Bates *et al.* 1989), as understocking may result. Furthermore, management plans should not count on retrieving the residual trees at a later date because re-entering the stand will cause significant damage to aspen suckers (Schier *et al.* 1985).

White birch

White birch readily seeds into clearcut areas, often dominating the site and outgrowing aspen seedlings (Smith and Ashton 1993). It regenerates on sites through a combination of suckering and seeding. Regeneration is best on bare mineral soils, such as those found after fire or following litter disturbance by logging (Safford *et al.* 1990). White birch disperse seeds in the fall (Safford *et al.* 1990), and clearcutting operations could begin in December following a good seed year. Site scarification is important as seed germinates best on mineral soil. For example, in Alaska, scarified sites were 100 % stocked with white birch; non-scarified sites were only 30 % stocked (Safford *et al.* 1990). Scarification can be accomplished through logging (best done in snow-free periods), disking, or controlled burns (Safford *et al.* 1990).

Tulip tree

Clearcuts have been used to regenerate tulip trees in the Appalachians (Smith and Miller 1987), but this system would probably not succeed in southern Ontario since this species usually occurs as scattered, uncommon individuals within a stand (i.e., too few tulip tree seed sources). Patch clearcuts might be an option in larger stands providing that there is a substantial seed source. This type of regeneration is covered under group selection (**Section 6.1**).

Minimizing the negative impacts of clearcutting

Patch cutting can help to reduce some of the negative aspects of the clearcutting system (**Box 6.4.1**). For example, a 30 ha stand of aspen could be cut in patches. Five, 15-year rotations amounts to 75 years or approximately the rotation age of aspen. One 5-ha patch could be clearcut every 15 years, creating a variety of age classes and wildlife habitats in the landscape. The sixth 5-ha patch could be left to decline as old growth aspen, eventually being replaced by more tolerant tree species. Variations of this scenario could apply to a variety of different stand conditions, or other early successional hardwood species, provided the stand is relatively large (i.e., applicable in very few southern Ontario stands). Small clearcut patches also provide excellent habitat for ruffed grouse (McCaffrey *et al.* 1997) provided that such stands are adjacent to more mature stands that provide other grouse habitat needs. A network of different-aged patches also benefits moose, deer, black bear, marten, fisher, lynx, and fox (Davidson *et al.* 1988).

4. Managing succession to a tolerant hardwood, pine, or cedar forest cover type

If advanced regeneration of desirable tolerant hardwoods, pine, or cedar exists in the understory of a mature early successional hardwood stand, these understory species could be managed to later become the dominant species on the site. The understory trees may range in size from seedlings to polewoods with an intermediate crown position. The key to successful release of this understory is to wait until it reaches a size where it can shade out any aspen regeneration and aspen suckers can no longer overtop it.

Box 6.4.1. Considerations for minimizing negative impacts when using the clearcut system.

- Anticipate possible environmental impacts (e.g., increased streamflow, soil erosion); uncut buffers should be left around significant features including streams and seepageways.
- Determine presence of any significant wildlife habitats (e.g., habitat for rare species, seasonal concentration area, especially for songbirds during migration, ruffed grouse, woodcock).
- Avoid scheduling clearcutting operations during critical times of year for wildlife (i.e., March-August breeding season).
- Adjust the size, shape, and orientation of clearcut patches, depending on site and objectives (e.g., wildlife habitat creation).
- Use site quality and objectives to locate patches (e.g., create openings in areas likely to provide most benefit to wildlife, provide greatest chance of successful regeneration or improve site conditions for target species, minimize site damage due to erosion).
- Do not locate clearcuts on poor sites (e.g., ridges, frost pockets, poorly drained areas) as these sites will be difficult to regenerate.
- Anticipate other potential problems following harvest (e.g., severe browsing by deer, competition by shrubs and/or other undesirable vegetation, increase in invasive exotic vegetation).
- Retain some trees (e.g., at least 6/ha) to provide wildlife habitat (e.g., snags for perches, large trees for dens and/or nest cavities).
- If applicable to silvicultural objectives, protect established (advanced) regeneration of desired species.

First-year height growth of aspen suckers can be quite high, ranging from 0.3-1 m. Height growth usually slows after this point, as the stem produces lateral branches (Davidson *et al.* 1988). The desirable species in the understory should probably be at least 3 to 4 m tall before they are released; otherwise they might be rapidly overtopped, resulting in a mixed stand or pure aspen stand. A minimum stocking of advanced regeneration is also required before canopy removal treatments begin. Ideally there should be a healthy, vigorous understory tree approximately every 3 m.

If the early successional canopy is too thick for the understory to grow and reach the desired height of 3 to 4 m, the canopy may have to be thinned to promote understory growth. Thinning should be light however, so as not to promote the regeneration of early successional species. Canopy basal areas should not be reduced below 24 m^2/ha**.** Diseased and poor quality stems could be removed from the canopy in these stands thereby promoting growth of the best stems, understory seedlings, and saplings, prior to canopy removal.

Once the understory is established satisfactorily, the canopy of early successional species should be removed if there is a market for the material. Otherwise the trees can be left to die naturally. If the landowner wishes to accelerate succession to more tolerant species, the stems could be girdled or treated with herbicide. Girdling or killing with herbicide is preferable as it should result in less damage to the understory, and killing with herbicide will eliminate root suckers. **Section 8.1** provides more information on vegetation management guidelines, including girdling and/or herbicide treatment options for polewood size stems.

On sites with little or no understory of desirable species, and/or isolated stands where suitable seed sources for desirable species are not found in the vicinity, underplanting is an option. For example, white pine has been successfully established under hybrid poplar plantations in eastern Ontario.

Planting spacing of white pine should be close, either 1.5 by 1.5m or 1.8 by 1.8m. These spacings are used by the Ontario Ministry of Natural Resources under shelterwood cuts, and are also recommended by the United States Department of Agriculture to help control white pine weevil and blister rust (Katovich and Mielke 1993). Once the planted trees are well-established and 3-4 m in height, the canopy is removed. Or a partial cutting of poplar (e.g., take one, leave one) might be conducted to release the pine but still maintain adequate canopy closure to minimize damage to pine by weevils.

Intermediate to shade-tolerant species that are suited to the soil texture and moisture conditions of the site could be underplanted under early successional canopies. An appropriate species list for underplanting could be determined by inventorying tree species in nearby forested stands that are located on similar site types. Landowners are encouraged to plant a variety of suitable species.

5. Managing stands with a small early successional component

Many stands in southern Ontario have a small component of early successional species mixed in with tolerant hardwoods, pines, or cedar. This section presents options for maintaining pockets of early successional Carolinian species such as tulip tree or sassafras in tolerant hardwood stands. Both tulip tree and sassafras are shade-intolerant species that are found growing with maples, oaks, and other more shade-tolerant species in southwestern Ontario. Retaining these uncommon species in a stand enhances species diversity.

Neither tulip tree nor sassafras can reproduce successfully under the lower light levels of the understory created by the single-tree selection system commonly used to manage tolerant hardwoods. However, these species can regenerate successfully in the larger canopy openings created by the group selection system (Weigel and Parker 1997). Refer to the tolerant hardwood section for more detailed information on group selection.

To regenerate tulip tree using the group selection system, use the following guidelines (Beck 1990):

- The opening diameter should equal the height of the stand (i.e., approximately 30 m). This is a compromise since diameter and height growth are slowed if openings are smaller than 1.24 ha, but the small size of most forest stands in southern Ontario does not realistically allow the creation of openings this large.
- Openings should be placed downwind and within 60 m from good tulip tree seed sources.
- Openings should be created following good seed years. In the US, good seed crops are produced annually; they may be less frequent in southern Ontario.

- The site should be scarified (i.e., scuffed up) to expose mineral soil and well decomposed organic matter, the preferred seedbed for tulip tree seed germination.
- Cutting and skidding should be conducted in the fall to expose mineral soil and to allow germination of seeds that must overwinter in the soil seed bank to be viable.
- Any tulip trees that are cut while creating openings should successfully reproduce through stump sprouts. Cutting in the winter dormant season will encourage regeneration by sprouting.

To regenerate sassafras using the group selection system use the following guidelines (from Griggs 1990):

- The opening diameter should be equal to stand height (i.e., approximately 30 m).
- Openings should be located downwind from and near suitable mature sassafras seed trees. It is not known how far sassafras seeds will travel from the parent tree, but they are broadly disseminated by birds, small mammals, and water. Limited predictable distribution of seeds from parent trees, however, may limit success with the group selection system.
- Any sassafras left intact in group selection openings should readily produce root sprouts that can help to regenerate the site. Cut sassafras will readily produce stump sprouts, and cutting in the winter dormant season will encourage regeneration by sprouting.
- A moist loamy soil with a protective layer of leaves and litter is the preferred seedbed, so site scarification is not necessary.

Stands should be thinned as described in the tolerant hardwoods section, and tulip trees and sassafras would be preferred crop trees.

If the management objectives do not include retaining some of the early successional hardwood component, then the stands should be managed using the silvicultural options appropriate for the dominant species or forest cover type and stand structure.

CONIFEROUS FOREST TYPES

Introduction

In this guide, a coniferous forest is comprised of at least 75 % conifer species. In southern Ontario, dominant species include white pine, eastern white cedar, eastern red cedar, eastern hemlock, and to a lesser extent, white spruce, balsam fir, and red pine. Coniferous forests are more common in northern areas of southern Ontario where the climate is colder and the growing season is shorter. They are often found on shallow or coarse-textured deep soils subject to limited moisture availability; cool areas such as north-facing slopes; very stony soils; in areas with heavy shade where tolerant conifer species can thrive; or in very wet areas.

Soil textures range from sand to clay; soil moisture regime ranges from dry (MR Ø, 0) to wet (MR 7-9); soils drainage classes range from very rapid (DR 1) to poor (DR 7).

In general, conifer species compete well with other species, including most tolerant hardwoods, on less productive sites (i.e., inadequate soil moisture, depth, nutrients) because the latter grow slower here than on more productive sites, allowing the conifers to compete and eventually predominate. Many conifer species are among the first trees to colonize a site after a disturbance. Establishment of white pine, red pine, and jack pine is promoted by fire. Eastern red cedar and white pine readily establish themselves in old fields.

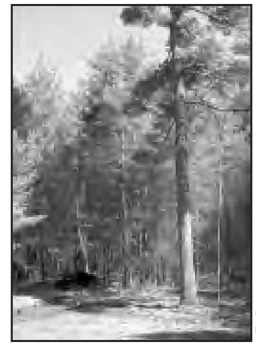
Understory vegetation diversity is often low in conifer stands because high year round shade limits the number of species that can thrive. In addition, the density and basal area of these stands are often higher than in mixed or deciduous forests, thereby severely limiting the growth of other species. Also the accumulation of acidic litter leaches many cations from the surface mineral soil horizons. However, mosses and liverworts are common, as well as some shade-tolerant shrubs and herbaceous plants.

This guide provides silvicultural guidelines for three commonly-occuring conifer forest cover types found in southern Ontario: pines (both white and red pine), cedars (both eastern white and eastern red cedar) and hemlock. Other conifer species occur in southern Ontario, for example red and white spruce, but usually only as scattered individuals in natural forest stands.

Red spruce is found primarily in Site Region 5E (within Algonquin Park), but scattered occurrences have been reported in Site Region 6E (southeastern Ontario). Due to its rarity, management objectives should focus on conserving red spruce (**Appendix B**). Since this species requires a sheltered site for regeneration, group or single tree selection is recommended in stands where red spruce occurs. Mature red spruce should not be harvested until red spruce regeneration is well established.

Similarly, the less rare white spruce also occurs as relatively small, scattered populations at the southern edge of the species' Ontario range. In northern Ontario where white spruce is common, clearcutting is recommended for white spruce stands and uniform shelterwood for mixed stands). In southern Ontario the management focus for stands that contain white spruce should be conservation, and use of uniform shelterwood is recommended. White spruce and other regeneration should be well established before the final harvest occurs. Silvicultural guidelines for white spruce are provided in "*A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*" (OMNR 1998*b*).

6.5 PINES


E. Boysen

by Peter and Erin Neave, and David Bland

Introduction

White pine is the most widespread and common pine in southern Ontario. It is found on a wide variety of sites and soil textures and thrives in full sunlight. In many parts of this region, it is most often occurs on drier, sandy soils but usually grows best on moist, sandy loams. In Site Region 6E it is a common tree of mixed forests and is frequently found growing in small pure stands or with hemlock, red oak and/or white oak. In Site Region 7E it is commonly associated with oaks. In can grow and persist in forests with a relatively open canopy.

In southern Ontario, natural red pine is not nearly as common as white pine. It is intolerant of shade and found on relatively infertile sites, often on sand plains, ridges, and rock outcrops. In this region, red pine occurs most often as scattered individual trees within a larger stand. White pine is a common associate. Occasionally it is found in small pure stands or with hemlock. In the past, (1920 to 1990), this species was planted extensively in plantations.

Natural jack pine is very uncommon in southern Ontario, occurring only in Site Region 6E on the Bruce Peninsula and in the Kaladar region. It is also intolerant of shade. It tends to grow on dry sandy soils and rocky outcrops. In this region, this pine most commonly forms pure stands, but can be found with white birch, white spruce, red maple, and poplars. This species is also dependent on fire for successful regeneration and perpetuation. It has been sporadically planted in plantations.

Pitch pine is a provincially rare species (S3) found only in Site Region 6E. In this area it usually occurs on rocky ridges, often where soils are too shallow and dry for most other species. More common associates include red oak, white oak, white pine, and red cedar. It is intolerant of shade. This species will likely prove difficult to manage and its perpetuation probably depends on repeated fires.

Dry-fresh pine coniferous forest ecosite (FOC1)

Canopy closure is usually greater than 75 %, except where occasional gaps occur from tree mortality or windthrow. As canopy closure increases, understory diversity (e.g., shrubs and herbaceous plants) usually decreases.

This ecosite is most commonly found on upper to mid-slope and tableland topographic positions on droughty, shallow soils over bedrock, rock, sands, and coarse loams. Shallow soils can be over limestone or granite; on some sites they may be almost completely replaced by slabs of limestone. Local site conditions are often extreme enough (i.e., dry, shallow soils) to limit the growth of other species.

This ecosite consists of two forest types. The dry jack pine coniferous forest type is dominated by jack pine with white pine, red pine, red maple and several oak species as more common associates. The only natural stands of jack pine in southern Ontario occur in the Tweed-Kaladar area, on shallow soils over granitic bedrock, and on the northern half of the Bruce Peninsula on shallow soils over dolostone bedrock. Due to its limited natural distribution in southern Ontario, this guide does not provide silvicultural guidelines for this species which is rare in Site Region 6E and absent from Site Region 7E. Readers interested in forest management of this species, should refer to:

OMNR. 1997. Silvicultural guide to managing black spruce, jack pine, and aspen on boreal forest ecosites in Ontario. Version 1.1. Ont. Min. Nat. Resources, Queen's Printer for Ontario, Toronto. Three books. 822 p.

In the dry-fresh white pine-red pine coniferous forest type, white pine or red pine dominate the site, either separately or together. The distribution of red pine is limited in southern Ontario. It is scattered throughout eastern Ontario as a minor component of other stands. It is also found on beach-dune complexes at Pinery and Wasaga Beach Provincial Parks, and at Alliston Pinery (i.e., natural occurrences are rare in 6E and 7E). Coniferous forests of white pine are common in Site Region 6E, particularly in the northern parts of eastern Ontario, and are also found sporadically on sites such as the beaches at Wasaga. In Site Region 7E there are small remnant stands that were logged, but this species rarely occurs in pure stands.

Dominant Trees	white pine, red pine, or jack pine
Less Common Associates	oaks, white cedar, white birch, hemlock, balsam fir and red maple
Common Shrubs	low sweet blueberry, common juniper, wintergreen, buffalo berry, serviceberries, and sweet fern
Common Herbs and Ferns	bracken fern, gaywings, Canada mayflower, wild sarsaparilla and large-leaved aster
Soil Moisture Regime	dry (MR 1, 0) to fresh (MR 1, 2), occasionally moist (MR 4-6)
Soil Drainage	Very rapid (DR 1) to imperfect (DR 5)
Equivalent Ecosite in Central Ontario	ES14 (also ES11, 12, 13)

This chapter will focus primarily on white pine, with red pine as an associate. Silvicultural treatments for managing jack pine have already been thoroughly covered by silvicultural guides for northern Ontario. Due to the rarity of natural stands of this species in this region, management objectives will have a greater emphasis on protection and ecological restoration than on forest management.

Changes since the presettlement era

In the postglacial period of the last 12,000 years, white pine abundance and distribution have changed substantially. White pine probably survived the Ice Age on the continental shelf and then slowly colonized eastern North America as the ice retreated. It thrived best in areas where the frequency of forest fires was relatively high and precipitation was not much greater than transpiration (Jacobson and Dieffenbacher-Krall 1995). White pine appears to have declined over the past 4000 years as a cooling of the climate allowed boreal species to move southward and fire frequency decreased (Jacobson and Dieffenbacher-Krall 1995). Fire encourages white pine regeneration by exposing mineral soil ideal for seedling establishment.

Since early settlement, the natural distribution of white pine has decreased due primarily to intense harvesting and its more specific regeneration requirements. High-grading harvests occurred frequently, removing mainly the biggest and best trees. In the early 1800s the Europeans cut red and white oak and pine mostly for the naval industry. Later that century the Americans imported high quality Canadian hardwoods, pine sawlogs, and lumber.

In southern Ontario planting programs subsidized by the OMNR have probably broadened the distribution of red pine and jack pine. Initially planting was done to stabilize marginal agricultural land, particularly the blowsands of St. Williams Forest Station, and the Simcoe County, York Regional, Durham Regional, Limerick and Larose and other former Agreement Forests. More recently, large areas of marginal farmland have been retired under Woodland Improvement Agreements (WIAs), thereby further increasing the range or occurrence of planted red and jack pine.

The use of fire by settlers to clear land following logging greatly increased the frequency of uncontrolled fires. Railways started many fires as well. Many of these fires were severe and repeated burning may have contributed to soil sterilization in some areas. In eastern Ontario, studies conducted at the turn of the century demonstrated that the diversity and density of trees were lowest in areas subject to more burns (Keddy 1993). The amount of white birch, red and white oak, and red and jack pine increased with repeated burning.

Choosing an appropriate silvicultural system

Selection of the most appropriate silvicultural option(s) depends on several factors including:

- an understanding of the autecology of the pine species of interest
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed below.

Autecology of eastern white pine

Some knowledge of the autecology of eastern white pine can help to improve the likelihood of successful silvicultural management of forest types with a dominant component of this species. Important biological information for white pine is listed below and additional information is provided in **Appendix B**.

Reproduction and early growth (Wendel and Smith 1990)

a) *Seeds and germination*

- Good seed years occur every three to five years.
- Seed is dispersed within a month of cone maturity and travels distances of 60+ m in closed stands and 210+ m in the open. Dispersal by squirrels was found to be responsible for most successful reproduction in New Hampshire.

b *Site factors*

- Seeds can germinate on both disturbed and undisturbed litter layers.
- Under full sunlight, moist mineral soil, *polytrichum* moss and short grass cover of low density are suitable seedbeds; dry mineral soil, pine litter, lichen and very thin or very thick grass covers are not suitable.
- Poor seedbed conditions can be overcome by scarification and/or shading.
- Overstory shading in a shelterwood cut has proven to be ideal, but shade from slash or competing hardwoods eventually proves detrimental.
- White pine growth rates are better on sandy or loamy sites than on soils with high clay content (Williams *et al*. 1990).

c) *Early growth*

- After establishment, light intensity is critical to the growth and survival of seedlings; at least 20 % of full sunlight is required for survival.
- Early height growth is quite slow for the first 10 years, but then may become quite rapid.

Reaction to competition (Wendel and Smith 1990)

- White pine is intermediate in shade tolerance and competition can be a major problem (Gillespie and Hocker 1986*a*). Trees can survive in as little as 20 % of full sunlight but it takes 45 % of full sunlight before maximum height growth is reached.
- Competition is much more serious during the seedling stage since height growth of white pine is relatively slower than that of its associates. If white pine can survive to the sapling stage its chances of survival are greatly enhanced.
- When competing with light-foliage species such as birch (i.e., species allowing sunlight through their canopy), white pine can usually predominate. When growing with aspen, oak, or maple, white pine usually fails to gain a canopy position and often dies out.
- Pure stands of white pine rarely stagnate. Variations in site conditions and tree phenotypes result in differentiation into different height and diameter classes and the most vigorous trees create their own canopy positions.
- White pine less than 30-years-old and with greater than one-third of their height in live crown generally respond well to release. Young stands will grow much better following thinning. Response to release declines proportionately with increasing age and decreasing live crown height.

Factors limiting growth and development (Wendel and Smith 1990)

Young white pines have thin bark and are sensitive to fire damage; damage to the bark often provides a point of entry for disease. Older trees have thicker bark and have moderate fire resistance. Frequent fires (i.e., less than every 10 years) may eliminate white pine reproduction.

A total of 277 insects and 110 disease organisms attack white pine but only 16 insects and seven diseases are of commercial importance. White pine weevil, white pine blister rust, and *Armillaria* root rot are the most important. These are described below.

- White pine weevil kills the terminal shoot, including up to the last two to three years of growth. Entire trees are rarely killed by the weevil and a lateral branch generally takes over as a new leader. The problem lies in the crook produced in the bole and the resulting loss of merchantable log length and quality (Rose and Lindquist 1984).
- White pine blister rust attacks all stages of growth throughout the range of white pine, often causing mortality. The rust kills the cells of the inner bark and recently formed woody tissue. Small trees die quickly after infection. Older trees become weak at the point of infection and the rust often girdles the trunk, slowing growth and sometimes causing breakage (Natural Resources Canada 1994).
- *Armillaria* root rot destroys seedlings and saplings for distances of up to 9 m from hardwood stumps. The fungus radiates out and girdles pines at the root collar causing resinosis. The rot kills the outer wood layers and cambium, causing decay in both sapwood and heartwood (Natural Resources Canada 1994).
- Other pests include wood borers and bark beetles that both attack damaged or dying wood and recently felled trees (Rose and Lindquist 1984). White-tailed deer and snowshoe hare browse young white pine and can hinder its ability to re-colonize a site (Heinen and Sharik 1990; Steingraber 1990).

Autecology of red pine

Some knowledge of the natural history of red pine can help to improve the likelihood of successful silvicultural management of forest types with a dominant red pine component. Important biological information for red pine is listed below and additional information is provided in **Appendix B**.

Reproduction and early growth (Rudolf 1990)

a) *Seeds and germination*

- Good seed crops are produced at intervals of three to seven years and cones usually open on hot autumn days.
- The effective range of seed dissemination averages 12 m from the parent tree.
- Seedlings only become established when there is adequate rainfall (e.g., more than 100 mm for May, June, and July in northern Minnesota); without sufficient rainfall the seeds may lie dormant for up to three years.

b) *Site factors*

- Red pine naturally becomes established after fire. Moderately intense fires prepare the seedbed, kill some competing trees, control brush for several years, reduce cone insect populations, and produce an open overstory canopy.
- After a fire, specific conditions are still needed for stand establishment. These include: a good seed crop, a relatively thin layer of ashes, weather conditions favorable for germination and establishment, and freedom from fire for several decades. It is believed that this combination of conditions only occurs once every 75-100 years in north-central Minnesota.

c) *Early growth*

- Approximately 35 % of full sunlight is required for successful seedling establishment and they can attain maximum height growth with as little as 45 % of full sunlight. Red pine seedlings usually grow slowly in the wild, especially if partially shaded.

<u>Reaction to competition</u> (Rudolf 1990)

- With the exception of jack pine, red pine is typically less shade-tolerant than its common associates. Red pine grows best in even-aged groups or stands.
- Most natural red pine stands are under stocked.
- Young stands with less than 6200 trees per hectare seem able to thin themselves. Denser stands will stagnate but respond well to thinning.
- Maximum volume growth can be attained through thinning with spacing approximating 20 % of the height of dominants. Height growth can be stunted when spacing falls below 15 % of the height of dominants.
- In the absence of fire, the natural succession sequence in the Lake States appears to be jack pine, followed by red and white pine that are eventually replaced by the tolerant hardwoods. On infertile sites, red pine can be a long persisting sub-climax species. In eastern Canada succession may move from red and white pine to spruce-fir or eastern hemlock.

<u>Factors limiting growth and development</u> (Rudolf 1990)

- Fire can be especially damaging, killing trees up to 21 m tall.
- Of the 100 insects known to feed on red pine, only a few cause mortality or serious injury. Several species of sawflies defoliate and kill seedlings and may also damage older trees. The redheaded pine sawfly is the most serious pest of red pine plantations in southern Ontario. Trees in young stands may sustain mortality or injury from Saratoga spittlebug, Zimmerman Pine moth, or the European pine shoot moth. The European pine shoot moth frequently deforms young red pine and white grubs can cut the roots and kill seedlings in dry years. Red pine scale can kill or severely injure trees of all ages.
- Scleroderris canker can kill young red pine but rarely kills trees over 2 m tall. The infection starts at the branch tips and moves towards the main stem. The fungus grows around the stem and may girdle the tree or form a canker (Natural Resources Canada 1994). Red pine is also susceptible to a number of needle cast diseases.

- Ice and sleet storms and strong winds can cause serious breakage and windfall in red pine stands. This was seen in the ice storm of 1998 in red pine plantations across Eastern Ontario.
- Spring flooding can kill red pine in only 20 days.
- When population cycles peak, both the snowshoe hare and eastern cottontail rabbit can kill or reduce height growth of seedlings. When browse is scarce, white-tailed deer may browse and/or destroy seedlings. Porcupines girdle saplings to small trees.
- Red pine will not thrive in soils with free carbonates within 50 cm of the soil surface. Once the trees reach maturity and produce their first seed crop they will begin to show signs of stress and dieback and many will die.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.

Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands. Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Pine stands often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Large white and red pine are often the preferred nest trees for some birds of prey, including the endangered bald eagle (especially when the tree is located close to a productive waterbody). Eagles and ospreys frequently roost in large white pine. Also pine stands adjacent to suitable hunting areas (e.g., fields) are often winter roosting areas for several species of raptors. When tall enough to protrude above the main canopy, such supercanopy trees may attract songbirds and raptors, and provide refuge for mammals such as black bear and fisher.

In some parts of southern Ontario, natural conifer stands, especially older stands, have significant natural heritage value because they are an uncommon or even rare forest cover type. Therefore in these areas, management activities should not lead to an overall decrease in their area or representation within the larger region. The following provides further information on specific wildlife habitat provided by white, red and jack pine.

Box 6.5.1: Pine false webworm and European pine shoot beetle -- two introduced pine pests causing concern recently in southern Ontario.

Pine false webworm

The pine false webworm is an introduced insect that has been a serious pest for many decades in young plantations in Ontario. In 1992 it was observed defoliating mature and semi-mature red and white pine in Simcoe County and the Ganaraska Forest. However, the total area experiencing moderate-to-severe defoliation by this insect has declined for the second consecutive year to 1,457 ha in 1999 from 2,948 ha in 1998 and 8,755 ha in 1997 (Howse and Scarr 1999). Clearcutting and the experimental spraying of infected plantations have contributed to this decline.

This insect initially attacks older foliage, but once this is consumed, it begins feeding on current year foliage. Although trees can survive many years of defoliation, they do not add much new growth each year. In addition, older trees can tolerate less defoliation stress than younger trees. Up to 90 % tree mortality has been reported in a mature red pine plantation in Simcoe County.

Since it is a webspinning sawfly, applications of the bactericide *Bacillus thuringensis k.* are ineffective because it makes a web on the shoot, and then pulls in the needles on which it feeds. Currently, only chemical insecticides provide effective control. Recent experimental work has shown that the botanical insecticide Neem is effective when injected into the tree or sprayed from the ground or air. A registration package has been submitted to the Pest Management Regulatory Agency to have Neem registered for use against this and other sawflies. Managers of the Simcoe County and Ganaraska Forest have successfully controlled this pest by clearcutting the most heavily damaged sites in fall or winter, and leaving the slash on site. The adult insect emerges from the soil in the spring and lays eggs on the slash, but the larvae fail to reach maturity before the needles dry out (T. Scarr, OMNR, personal communication 2000).

European pine shoot beetle

This beetle was found in Ontario in 1992. Subsequent surveys have found it in several States, Ontario, and Quebec. Quarantine restricts the movement of pine products (e.g., logs with bark on them, Christmas trees, nursery stock) outside the affected area. In 2000, the quarantine applied to southwestern Ontario, west of and including Simcoe, Victoria, and Northumberland Counties.

The European pine shoot beetle attacks trees in two ways. Adults tunnel in the shoots of both healthy and stressed trees, causing the shoots to drop to the ground. The beetles also attack the trunks of stressed or dead trees, laying their eggs under the bark. The larvae then feed in the cambium, killing the tree.

In 1998, pine shoot beetles were reported consuming and killing Scotch, red, white, and jack pine in several locations in southwestern Ontario. Mortality was heaviest in Scotch pine (up to 90 %). Where native pines are killed, they are located close to heavily damaged Scotch pine. Other factors, such as drought and *Diplodia* tip blight, may also contribute to mortality. Research is underway to determine impacts, and whether Scotch pine must be present for the insect to reach damaging levels (T. Scarr, OMNR, personal communication 2000).

Insect populations can be kept low by removing slash and stressed, dead, or dying pines, and by cutting stumps close to the ground. Insecticides may have some effect, but have not been operationally tested.

White pine

Many mammals including beaver, snowshoe hare, cottontails, porcupine, red and gray squirrels, mice, and white-tailed deer eat seeds, bark, and/or foliage (Wendel and Smith 1990; Rudolf 1990). Many birds also feed on white pine seeds including the yellow-bellied sapsucker, black-capped chickadee, white-breasted nuthatch, pine warbler, pine grosbeak, and red crossbill (Wendel and Smith 1990). Wild turkey roost in large white pine (Kilpatrick *et al*. 1988). Mature white pine can provide winter cover for deer by intercepting falling snow thus reducing snow depth on the ground and by providing some thermal protection from harsh weather conditions. Both hemlock and eastern white cedar provide better winter cover.

Red pine

White-tailed deer, snowshoe hares, and cottontail rabbits browse seedlings and saplings. Porcupines eat bark and can girdle all sizes of trees. Red pine stands provide some cover and food and nesting sites for birds, as well as winter cover for deer and moose.

Jack pine

Jack pine stands provide food and shelter for white-tailed deer and snowshoe hare. Common understory shrubs associated with jack pine such as blueberry are also an important food source for many birds and mammals.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of stands of pine.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood or clearcut silvicultural systems and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Managing white and red pine stands

Both natural mixed stands of white and red pine and jack pine stands generally are even-aged, having become established after a catastrophic event such as fire. White pine, red pine, and mixed red and white pine stands are generally managed as even-aged stands as neither white nor red pine has adaptations to establish in small openings within a forest stand. The silvicultural systems best suited to managing even-aged stands include: the shelterwood system, the clearcut system, and group selection.

The decision key shown in **Table 6.5.1** was developed to help to select the most appropriate silvicultural options for a specific stand. Decisions are based on stand age and stocking. Follow the numbered decision points to reach a management option (in italics) that best describes the site and stand conditions. Then read the accompanying description for further details on the management option.

Table 6.5.1: Decision key for white and red pine management in southern Ontario.

Text Description	Decision Factor	Continue to Point No.
1.	Stand age is:	
	a. immature (less than rotation age) ………………………………………….	2
	b. mature (rotation age): *Harvest and regenerate the stand* ……………….……	3
2.	Stand composition is:	
	a. mixed white pine and/or red pine with hardwoods: *Use crop-tree management to thin pine for maximum growth*	
	b. primarily white pine or red pine: *Use crop-tree management OR density management diagrams to thin pine stems for maximum growth*	
3.	Stand species composition is:	
	a. primarily white pine and red pine and uniformly distributed ………………	4
	b. white pine and red pine with a red oak and/or white oak component ……..	6
4.	Stand stocking is:	
	a. at least 12 m^2 /ha in pine: *Use the uniform shelterwood system*	
	b. less than 12 m^2 /ha in pine ………..……………………………………	5
5.	Landowner objective is to:	
	a. increase or maintain white or red pine component in the stand at the expense of undesired species: *Use patchcut with seed trees* to create small pockets of white pine regeneration	
	b. in a stand of otherwise desirable species, for example tolerant hardwoods: *Use group selectio*	
6.	*Use the same guidelines as for white pine and red pine (options 4 and 5) but consider oak stems as crop trees as well.*	

1. Stand age

Silvicultural work and preparatory treatments for regeneration of white and red pine generally begin at a stand age of 60 to 80 years. Rotation age is generally 80 to 100 years (OMNR 1998*b*). Timing of silvicultural operations can also depend on site quality and the presence of damaging agents. If a damaging agent is causing the stand to begin to decline before rotation age, silvicultural operations should be considered at an earlier time.

2a. Crop-tree management

Identifying crop trees early and managing them with thinning and pruning can substantially increase timber quality and return on investment. Immature stands can benefit from crop-tree management if they are overstocked or stagnating. Crop trees are chosen and released from competition, improving stand vigor and volume production over time. The priority for crop-tree release is the removal of those trees that interfere with the development of selected crop trees (Perkey *et al.* 1993). Both thinning and pruning activities comprise crop-tree management. Each activity is discussed below.

<u>Thinning</u>

Thinning will benefit the stand by:

- increasing the amount of merchantable wood
- removing undesirable species
- removing poor quality stems
- improving stem vigor and quality (Gillespie and Hocker 1986*b*).

Thinning (i.e. the number of stems or basal area per hectare to be removed):will release a set number of trees per hectare. Thinning can be selective (i.e., removing trees based on their individual merits) or systematic (generally used in plantations where rows or strips are removed). Use of either crop-tree management or area-wide thinning is recommended. Area-wide thinning is discussed under “2b. Density management diagrams”.

Crop-tree release is recommended in even-aged stands of pure pine or mixed pine-hardwoods. The species chosen as crop trees will strongly influence the species present at rotation age and in subsequent stands. Careful selection of species improves the likelihood of accomplishing landowner objectives for the stand.

The following characteristics should be considered when choosing white and red pine crop trees:

- Crop trees should occupy a codominant or dominant position in the stand.
- The number of crop trees with V-forks in the stem or crown (V-forks are forks whose connection can be traced back to the stem) should be minimized.
- Ideally each crop tree should provide two straight 5 m (16 ft.) logs.
- Crop trees should have well-developed crowns (i.e., one-third or more of the height in live crown).

- Only a minimal portion of the crop tree should have persistent dead branches.
- There should be no open wounds in the stem and no evidence of fungi, insect, or disease susceptibility in the stem or crown.
- The top should be intact with few or no broken branches.

Hardwood crop trees in the stand should:
- be mast producing trees for wildlife
- be commercially valuable where possible (i.e., red oak and sugar maple are preferred to birch or aspen)
- have a dominant or codominant position and limited defects (e.g., V-forks, wounds) (Perkey *et al*. 1993)
- not be prolific seeders (e.g., sugar maple that will compete with conifer seedlings), unless conversion of stand to predominately hardwoods is an objective.

Approximately 370 crop trees per hectare (or 150 crop trees per acre) should be selected and released on two or three sides at the polewood stage, if the stand is stagnating (OMNR 1986). Trees whose crowns are touching the crown of the crop tree should be removed on two or three sides of the crop tree. This will provide room for growth of the crown of the crop tree. The need for and timing of further release operations before rotation age is reached will depend on the timing of the first release, the success of the first release, and the objectives of the landowner. Ideally crop trees should be released every time their crowns are crowded by the crowns of other trees.

Pruning

Management of white and red pine for lumber requires the production of stems that are clear or free of loose knots (Smith and Seymore 1985). Pruning is necessary, especially in white pine stands, because the rot resistance of white pine results in poor natural pruning ability (OMNR 1998*b*). Red pine growing in pure stands also exhibits poor natural pruning ability (OMNR 1998*b*). Natural pruning and form of both white and red pine are generally good in mixed stands and pruning treatments usually are not necessary (Smith and Seymore 1985).

In well-stocked stands of white and red pine, most lower branches are dead by the time pruning becomes necessary. It is normally easier to prune dead branches. Pruning of live branches should be carried out during winter months to minimize bark tearing and infection by disease or decay organisms. If live branches are pruned, avoid removing large live branches (greater than 3.7 cm or 1.5 in.), as these will be slower to pitch over and heart rot could be introduced (Smith and Seymore 1985; Perkey *et al.* 1993). Whether pruning live or dead branches, it is critical that pruning be done adjacent to the branch collar without injuring the branch collar or leaving a stub.

When pruning, do not reduce the live crown ratio by too much because this will stunt height growth (Smith and Seymore 1985). No more than one-quarter to one-third of the live foliage should be removed at any one time, less if pruning is done in several stages over a period of several years.

Managers may wish to leave crop-tree pruning until thinning operations have been conducted for the following reasons:

- there is less risk of physical damage to pruned crop trees (Smith and Seymour 1985)
- there is no risk of pruning trees that subsequently must be removed during thinning.
- to ensure selected trees have good vigor (Smith and Seymour 1985)
- to ensure branch stubs cover over quickly since thinning creates conditions favoring rapid growth (OMNR 1998*b*).

However, sometimes it may be advantageous to prune before thinning takes place, depending on available labor and markets for the small material from the thinnings. Also branches will be smaller when trees are pruned at an earlier age, although there will be a higher percentage of live branches.

Whether pruning before or after thinning, crop trees for pruning must be selected and marked by an experienced marker. Crop trees should be selected from dominant or codominant trees. When pruning before thinning, provision for initial row or strip thinning must be made by not selecting crop trees within rows or strips that will be removed in the initial thinning.

The first pruning is generally conducted after the trees have reached a height of the first log length for white pine and are in the polewood stage (10 to 15 cm in diameter). At this stage, if the first log length is straight, future white pine weevil attacks on the trees cannot affect that portion of the stem (Smith and Seymour 1985).

Approximately 370 trees per hectare (or 150 trees per acre) should be pruned (OMNR 1986).

Pruning can be done in two or more stages with a different length of tool or ladder for each zone of height. Pruning to a height of 5.5 m (17 ft.) will encourage the first 5 m (16 ft.) of log to be free of loose knots and decay (Smith and Seymour 1985).

2b. Density management diagrams

The preferred method to thin pine stands using area-wide thinnings is to use density management diagrams to manage growth.

The relationship between stand density and tree size can be used to enhance volume production in a stand. High density does not directly cause mortality, however density is related to competition that can lead to a decline in vigor and greater susceptibility to damaging agents such as insects and disease (Smith and Woods 1997). High densities and low vigor can cause stands to stagnate in growth. Thinning the stand will release some trees, increasing vigor and volume production.

In even-aged pure stands, the optimum level of stocking for an average tree size can be predicted using density management diagrams. **Appendix E** provides red and white pine density management diagrams and an explanation of their use.

In general, area-wide thinnings are conducted when using density management diagrams. Area-wide thinnings differ from crop-tree release thinnings. Instead of choosing crop trees and releasing them, inferior trees are chosen throughout the stand and removed releasing larger numbers of residual “crop” trees. To apply an area-wide thinning, first determine the number of trees to be removed using the density management diagrams. Convert this number to basal area using the following formula:

Initial basal area = initial sph*DBH*DBH*0.00007854

Basal area after thinning = residual sph*DBH*DBH*0.00007854

Where:

initial and residual sph = number of stems per hectare before and after thinning operations, and

DBH = average diameter at breast height. Note that this will be a larger value after thinning than before it.

The difference between initial basal area and basal area after thinning is the basal area to be removed. Mark the stand to reduce basal area by this amount. Trees that should be marked for removal include:

- those with intermediate crown positions
- undesirable species
- those with deformities including V-forks, large open wounds, diseases such as blister rust, crooked logs from weevil damage, and dead tops or dieback
- trees with below average diameter
- trees with narrow or shallow crowns.

Commercial thinning operations can be considered in mixed white/red pine and hardwood stands, although this might require delaying the treatment until a stand age of 30 to 40 years for white pine and 25 to 30 years for red pine (OMNR 1998*b*).

In thinnings after the age of 50, it is recommended that the site be disturbed to encourage the establishment of white pine in the understory (Perkey *et al*. 1993). The optimum seed bearing age for white pine begins at 50 years. If hardwood regeneration is undesired, control with herbicides or brush saws may also be initiated after this age to promote the development of white or red pine regeneration (Perkey *et al*. 1993).

3. Stand species composition

If the stand is primarily red and white pine, see points 4 and 5 in **Table 6.5.1.** However, if the pine stand contains red and/or white oak, both common associates of white and red pine, it may be worth managing the stand to promote regeneration of these valuable hardwood species, as well as the pine.

4. Stand stocking influences choice of silvicultural system for regeneration

Once the stand reaches rotation age, attention turns to final harvest and regeneration of the stand. The density and distribution of pine in the canopy will determine the choice of the most appropriate silvicultural system for regenerating the stand.

Where there is greater than 12 m^2/ha in white pine and/or red pine in the stand, a uniform shelterwood cut is the preferred method of regeneration. This basal area will give a uniform distribution of seed trees over the stand and allow for an adequate amount of seeding in from the residual white or red pine.

Where there is less than 12 m^2/ha, a clearcut with seed trees or group selection cut may be more appropriate because there will be fewer pine seed trees and greater competition from less desirable species.

Uniform shelterwood

Uniform shelterwood can be used for pure stands of white pine, red pine, and mixed stands where an overstory exists. The desired species should be present in sufficient amounts (greater than 12 m^2/ha) so that a post-cut condition approximating the target crown closure level is achieved (OMNR 1998*b).* This system has some disadvantages when used to regenerate red pine because of the infrequent seed crops and strict environmental requirements for the establishment and growth of this species. Red pine establishment must be carefully checked following silvicultural work and artificial regeneration may be necessary in some cases (Rudolf 1990; OMNR 1998*b*).

A four-cut uniform shelterwood system should be used when the stand has the following conditions:

- greater than 50 % of the desired species of white pine, red pine, mixed white pine/red pine, or mixed pine with red or white oak (discussed in a following section)
- greater than 70 % stocking
- a greater proportion of white pine than red pine.

A two or three-cut uniform shelterwood system should be used when the stand has:

- only 30 to 50 % of the desired species or
- more red than white pine.

The four-cut and the two- or three-cut uniform shelterwood systems are the same with the exception of the removal cut. The uniform shelterwood system for pines is explained below. Differences in the four-cut and two- or three-cut systems are outlined in the description of the removal cut. The first cut is called a preparatory cut, the second is called a regeneration or seed cut, and the third and fourth cuts are referred to as removal cuts.

Preparatory cut

The preparatory cut is recommended for stands in the 61- to 80-year age class to enhance crown development. Young overstocked stands may have under-developed crowns that are too small for adequate seed production. This cut is appropriate where crown diameter is in the 4 to 5 m range. A preparatory cut may also be used to remove undesirable species from the stand in preparation for the regeneration of white and/or red pine.

Residuals trees (i.e., trees to be left on site) should be:

- codominant or dominant in canopy position
- uniformly distributed through the stand
- the desired species, especially white pine. While these species should be favored, the importance of other species for wildlife and conservation values and biodiversity objectives must be recognized.
- other desirable species that may exist in the stand (e.g., red and white oak) that can be favored in a preparatory cut in efforts to ensure a good seed source (OMNR 1998*b*).

Some site disturbance during this cut will encourage establishment of white and red pine seedlings in the understory (Perkey *et al*. 1993). This may be partially accomplished through summer logging, where this does not jeopardize other forest values.

The space created between crowns should provide for further crown development. A full crown spacing between residual trees, or spacing of one-third of the average tree height between residuals, should result in a 50 % level of crown closure.

Regeneration or seed cut

This cut is recommended for stands in the 81- to 100-year age class or approximately 20 years following a preparatory cut, to facilitate natural regeneration. Tree crowns should be 6 to 8 m in diameter to fulfil regeneration targets.

Residual trees should be:

- codominant or dominant in canopy position
- the desired species
- free of defects, with good form and symmetrical crowns

The stand should be thinned from below, concentrating on removing defective, low quality trees first while leaving high quality residuals for site protection, and seed and wood production. Crown closure should be reduced to 40 to 50 % to promote the growth of white pine seedlings while protecting them from destructive pests such as white pine weevil and white pine blister rust (**Box 6.5.2**). This crown closure may be achieved by one-half crown width spacing (i.e., if crown width is 4 m, one-half crown width spacing is 2 m) or spacing trees to 40 % of their height.

When dealing with stands that are predominantly red pine, canopy density should be reduced to 35 % crown closure or full crown spacing (OMNR 1998*b*).

Box 6.5.2: Control of white pine blister rust and white pine weevil.

Some research has indicated that the best way to reduce damage from white pine weevil and white pine blister rust is to manage young white pine under an existing overstory. The overstory reduces the formation of moisture on seedlings or saplings required for rust infections. Shade from an overstory is also detrimental to white pine weevils because it cools the local environment and slows terminal shoot growth. White pine weevils also prefer large diameter terminal branches and tend to avoid the smaller ones growing in shade (Katovich and Mielke 1993). It is important to balance the appropriate light requirements for maximum growth and development of white pine on a site, while still maintaining an overstory component to mitigate impacts from these commercially important pests.

Removal cut

This cut follows the successful establishment of natural regeneration on the site. The timing of this cut depends on factors such as:

- the period of establishment for regeneration of desired species (e.g., white pine, red pine)
- the success and vigor of established regeneration. Ideally there should be a white or red pine seedling every 1.8 m to provide a fully stocked stand.
- the need to control competing hardwood vegetation to release pine so that they can grow to the height standard
- the growth and increase in value of shelterwood trees
- the need to ameliorate impacts of white pine weevil and white pine blister rust (**Box 6.5.2**).

This cut may be carried out in two stages: a release cut, followed by a final removal cut in a four-cut uniform shelterwood system OR as a single removal cut in a two- or three-cut uniform shelterwood system.

Release cut (i.e., stage three of a four-cut uniform shelterwood)

In a release cut, 30 to 40 % canopy closure is maintained. This is approximately equal to one full crown spacing between residual trees. A release cut will provide extended canopy protection for white pine seedlings from white pine weevil and white pine blister rust. As with previous cuts, the best quality residuals should be favored for their future timber value (OMNR 1998*b*).

Final removal cut (i.e., stage four of a four-cut uniform shelterwood)

The final removal cut occurs when regeneration height is 5 to 6 m. Some of the large residual trees could be retained even following this cut as seed trees, cavity trees, or supercanopy trees. These trees have wildlife value and by retaining them this silvicultural system will better mimic disturbances such as intense fires, the natural disturbance regime for pine, that might have left the largest, thick-barked stems. Ideally, supercanopy and cavity trees should still be healthy and vigorous and have the ability to persist for many years. Many of them also provide habitat for numerous species of birds that eat the white pine weevil (OMNR 1998*b*). These trees could be identified in an earlier stage for retention.

Single removal cut (i.e., final stage of a two- or three-cut uniform shelterwood)

The single removal cut is recommended if there is little risk of white pine weevil damage and if a minimum of 1000 seedlings/ha will remain uniformly distributed over the site after the final removal cut is made. This cut can be made once regeneration has reached a height of 1.5 m for white pine and 1.0 meter for red pine. Some of the large residual trees should be retained for their wildlife values.

When stands are dominated by red pine, a single removal cut is recommended because red pine requires a quick release from overstory shading. If the release is delayed, the red pine regeneration cannot successfully compete with more shade-tolerant species such as white pine, white spruce, red maple, and balsam fir.

5a. Patch cut with seed trees

Patches are clearcut to maintain or enhance the conifer component (e.g., white or red pine) in stands with a significant proportion of hardwood species. Also this option can be used to restore white and red pine to their appropriate ecosites or to maintain these species at current low levels of abundance in stands with less than 12 m^2/ ha of pine (OMNR 1998*b*). Due to the small average size of forest stands in southern Ontario, a maximum size of 2 ha or less is recommended for this option.

One to 2 ha patches are clearcut, retaining 10 to 35 seed trees per hectare of the desired pine species well distributed across the site. The selected trees should have the following characteristics:

- high quality
- codominant or dominant crown position
- a windfirm position
- a wide crown
- the capacity to produce viable seed.

For stands dominated by red pine, it is recommended that seed trees be one tree length apart where possible.

Site preparation may be required for white or red pine seedlings to establish themselves. Disturbing the site mechanically, chemically, or through prescribed burning may increase its suitability for white and red pine colonization. This “scarification” has been shown to increase seedling survival and health for both white and red pine in a number of studies (Burgess *et al*. 1995; Weber *et al*. 1995; Herr *et al.* 1994).

Once white or red pine seedlings have become established, the seed trees may be removed. Some seed trees should be left as supercanopy and cavity trees to add structural diversity to the stand and provide habitat for nesting, denning, and foraging wildlife (Rogers and Lindquist 1992).

Understory vegetation management is critical; otherwise, intolerant hardwoods will gain a competitive advantage and eventually become predominant (OMNR 1998*b*). Competition from hardwood seedlings will probably need to be controlled with herbicides or manual methods such as brush saws (**Section 8.1**). Opportunistic species such as birch and aspen will grow much faster than white and red pine and eventually shade out the pine seedlings.

5b. Group selection

This silvicultural system is used when the landowner wishes to create small pockets of regeneration of pine in a stand where only a small portion of pine currently exists (e.g., less than 12 m^2/ha). However, managing young white pine in openings can be risky because small openings tend to collect cool air, providing adequate moisture formation for the development of white pine blister rust. Use of the group selection system will subsequently convert an even-aged stand to an uneven-aged stand.

To regenerate white and red pine using the group selection system, use the following guidelines:

- Size of canopy openings to be created should equal one to two times the height of the stand. White pine and especially red pine are not shade-tolerant and need more light than the typical one tree height openings created when managing mid-tolerant hardwoods.
- Openings should be placed downwind and within 60 m from a good white pine seed source or 12 m from a good red pine seed source (Wendel and Smith 1990; Rudolf 1990).
- In stands with an oak component, red and gray squirrels will cache white pine seeds and effectively disperse seeds (Wendel and Smith 1990).
- Openings should be created following good seed years. Good white pine seed crops are produced every three to five years after the age of 50 years; good red pine seed crops are produced every three to seven years after age 50 (Wendel and Smith 1990; Rudolf 1990).
- The site should be scarified (i.e., scuffed up) to expose mineral soil.
- No more than 20 % of the stand should be in openings at any one time.
- The next set of group openings is made in 20 years.

6. Managing white and red pine stands with a component of red and/or white oak

Red oak and white oak are common associates of pine in southern Ontario. Stands of white pine and red pine mixed with red and white oak can be managed in a similar manner to stands managed solely for white or red pine. Before managing mixed pine-oak stands it may be helpful to review the autecology of the oak species (**Section 6.2**).

The three silvicultural systems (i.e., uniform shelterwood, patch cut with seed trees, and group selection) should be applied as previously described for managing a stand for white and red pine, but the following factors should be kept in mind to increase the success of oak regeneration:

1. Suitable red oak or white oak crop trees can be identified and released prior to rotation age. At rotation age the appropriate silvicultural system should be chosen and implemented to regenerate pine with an oak component. The optimal management strategies for regenerating pine are quite

different than those for oak since maximum growth occurs at relatively high basal areas for pine (Hibbs and Bentley 1987). Oaks must be established and have adequate growing space to compete successfully with pines.

2. Both red oak and white oak regenerate through sprouting and seeding and although they initially have a slower growth rate than pine, they eventually catch up (Lloyd and Waldrop 1992). Red oak and white oak seedlings invest much more energy into rooting systems than pine and although they are slow to start, they are able to persist in the understory and respond well to release (Tworkoski *et al.* 1986). Every effort should be made to establish oak seedlings at the time of preparatory cuts so that they are well established by the time of the regeneration cut.

3. Both red oak and white oak will sprout from cut stumps. Oaks stems cut during the preparatory cut should sprout, depending on diameter/age, and be large enough to compete with germinating pine seedlings that become established after the regeneration cut. Oak sprouts grow much faster than seedlings and can readily compete with pine seedlings. The seedlings that establish themselves after the regeneration cut will likely not become part of the next stand (McGee and Loftis 1993).

4. White oak has a tendency to develop epicormic branches. Therefore, when selecting white oak crop trees and trees to be left as seed trees, avoid selecting those with existing epicormic branches and dormant buds that can become epicormic branches (Perkey *et al*. 1993).

Refer to **Section 6.2** for more details on oak regeneration.

The presence of acorns and the associated digging and gathering by wildlife contribute favorably to seedbed preparation for white pine (Alexander *et al.* 1985). The mix of oak and white pine also has its risks for white pine development. Damage to white pine from gypsy moth has been shown to increase with increasing proportions of oak in a stand (Brown *et al.* 1988).

S. Strobl

6.6 CEDARS AND CEDAR SWAMPS

by Peter and Erin Neave, Warren Schaffer and David Bland

Introduction

Cedars are often pioneer species that readily colonize open areas such as abandoned agricultural land and fields and can form pure stands. Some eastern white cedar stands in lowlands may have originated after hot fires burned areas leaving pockets of mature seed trees. The fires would have prepared a seedbed favorable to white cedar and would have eliminated any hardwood competition. Stand regeneration for eastern white cedar commonly occurs through both vegetative layering and seeding and is not dependent on large-scale disturbance; dispersal of seeds by birds is very important for regeneration of eastern red cedar.

Existing stands frequently represent second growth resulting from disturbance such as heavy grazing or management. However in undisturbed areas, uneven-aged stands of eastern white cedar associated with late successional stages can develop and persist because this species is very long-lived and only balsam fir can successfully regenerate under its canopy. Also eastern white cedar can do quite well in wet areas where few other species can compete successfully with it.

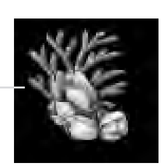
Eastern red cedar is intolerant of shade and depends on disturbance for successful establishment**.** In southern Ontario, agriculture and drought influence its distribution. Grazing promotes its dominance because cattle do not browse on it, but they do remove competing hardwood species. In southern Ontario, agriculture and drought influence its distribution. Fire is detrimental to this species and has been used to control it on active pastures.

Dry-fresh cedar coniferous forest ecosite (FOC2)

This ecosite is comprised of at least 75 % conifer composition. Canopy closure can vary greatly from relatively open or patchy to closed.

Sites conditions also can vary considerably. Sites dominated by red cedar are usually dry, and consist of shallow sands or coarse loams over limestone bedrock. However this species also does well on the deeper soils of pastures and old fields with a fresh moisture regime. Sites dominated by eastern white cedar are often shallow loams over fragmented limestone bedrock. It is also found along cliffs and escarpments consisting of limestone, dolostone, or granitic bedrock with a thin surface layer of soil, where few other tree species can survive. This ecosite is typically found on upper to mid-slope and tableland topographic positions.

There are two forest types associated with this ecosite. The dry-fresh red cedar coniferous forest type is infrequently encountered in Site Region 6E, being most common on the Napanee limestone plain. Pockets of this forest type also occur sporadically on drier ridges on the Frontenac Axis. There are small remnant stands in Site Region 7E that are now quite open and may be classified as woodland or savannah. Soil moisture regime tends to be dry. The dry-fresh white cedar coniferous forest type is found throughout southern Ontario. It is common



in Site Region 6E, in old fields and along the Niagara Escarpment, as well as sporadically in seepage ways, valleys, and on slopes. It is the most common cedar type on the Smiths Falls Limestone Plain. It is rare in Site Region 7E.

Dominant Trees	eastern white cedar, eastern red cedar
Common Shrubs	serviceberries, bush honeysuckle, low sweet blueberry
Common Herbs and Ferns	bracken fern, Canada mayflower, wild sarsaparilla, Canada bluegrass
Soil Moisture Regime	dry (MR∅, 0) to fresh (MR 1, 2)
Soil Drainage	commonly rapid (DR 2).

Fresh-moist white cedar coniferous forest ecosite (FOC4)

This ecosite occurs on both shallow and deep soils with a wide range of textures, including sands, loams and clays. It is typically found on basic or carbonate substrates and bedrock, on bottomland and lower to mid-slope topographic positions, as well as in seepage areas.

There are three forest types. The fresh-moist white cedar coniferous forest type is entirely dominated by eastern white cedar. It is common throughout Site Region 6E in lowland areas and around streams and wetlands. It is rare in Site Region 7E. The fresh-moist white cedar-hemlock and the fresh-moist white cedar-balsam fir coniferous forest types are also dominated by white cedar and primarily found in Site Region 6E.

Dominant Trees	eastern white cedar
Less Common Associates	balsam fir, hemlock
Common Shrubs	white pine, yellow birch, sugar maple, green ash, and white birch
Common Herbs and Ferns	mountain maple, dwarf raspberry, and alternate-leaved dogwood
Soil Moisture Regime	Canada mayflower, foamflower, enchanter's nightshade and goldthread
Soil Drainage	moist (MR 4-6) to fresh (MR 2, 3), poorly drained (DR 6) to moderately well drained (DR 4)

Dry-fresh white cedar mixed forest ecosite (FOM4)

This ecosite often represents second growth, developing on heavily managed sites, or grazed or disturbed sites.

It occurs primarily on sands and loams, often over basic and carbonate substrates and bedrock, in the dry to fresh soil moisture regimes. It is found on slope (e.g., valleys and seepage ways) and tableland topographic positions. There are two forest types associated with it. The dry-fresh white cedar-white birch and the dry-fresh white cedar-poplar mixed forest types are more common in Site Region 6E where they may colonize abandoned agricultural land and open fields. They may also occur sporadically on sites with cooler than normal microclimates. These forest types are rare in Site Region 7E, occurring sporadically along the Niagara Escarpment, and also on sites with cooler microclimates.

Dominant Trees	eastern white cedar
Less Common Associates	white birch, large-tooth aspen, trembling aspen, sugar maple, and/or white ash
Common Herbs and Ferns	wood fern, Canada mayflower, and dandelion
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1, 2)
Soil Drainage	very rapid (DR 1) to well (DR 3)

Fresh-moist white cedar-hardwood mixed forest ecosite (FOM7)

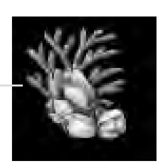
Mixed forests are defined as tree-dominated communities with greater than 60 % canopy closure, and having a composition consisting of conifer and deciduous trees, each contributing greater than 25 % canopy cover. Mixed forests are usually found on upland sites with moisture regimes ranging from dry (MR Ø, 0) to moist (MR 4-6). They commonly occur in shaded areas such as north-facing slopes, and in valleys and lowlands where the microclimate is cooler than normal. Soil pH is generally higher in mixed forests than in coniferous forests because the deciduous litter buffers the coniferous litter.

These forests are common in Site Region 6E (i.e., the Great Lakes-St. Lawrence Forest Region), but are uncommon in the Site Region 7E (i.e., Deciduous Forest Region). The composition of individual stands depends largely on site quality and disturbance. In general, deciduous trees tend to predominate on higher-quality sites. The exception is eastern hemlock, which often shares better quality sites with hardwoods because of its ability to grow in shaded conditions. Diversity in these forests is normally higher than in coniferous forests due largely to a milder local climate, improved site conditions, and lower density and basal area.

The fresh-moist white cedar-hardwood mixed forest ecosite occurs on sands, loams, and sometimes clays. Normally it occupies middle to lower slopes, seepage areas, and bottomland topographic positions.

There are two forest types associated with this ecosite. The fresh-moist white cedar-sugar maple mixed forest type is typically associated with the fresh moisture regime (MR 1-3) and is found especially along the Niagara Escarpment and on steeper river valley slopes. It is infrequently encountered in Site Region 6E and is rare in Site Region 7E. The fresh-moist white cedar-hardwood mixed forest type is more common on moister soils (MR 4-6), often along streams and seepage ways where white cedar does well. This forest type is common in Site Region 6E. It is rare in Site Region 7E, occurring sporadically along the Niagara Escarpment and in low cool areas.

Dominant species	eastern white cedar, red maple, yellow birch, white birch, and ash species
Common shrubs	mountain maple, alternate leaved dogwood, and dwarf raspberry
Common herbs and ferns	spinulose wood fern, marginal wood fern, wild sarsaparilla, jack-in-the-pulpit, and species of goldenrod
Soil moisture regime	moist (MR 4-6) to very fresh (MR 3)
Soil drainage	well-drained (DR 3) to very poorly drained (DR 7)



The following two ecosites have yet to be fully described by the ELC for southern Ontario.

White cedar mineral mixed swamp ecosite (SWM1)

This ecosite consists of white cedar with white birch, yellow birch, green ash, black ash, trembling aspen, balsam fir, red maple, balsam poplar, and white elm. Dominant species vary. According to the ELC for southern Ontario, it is found on mineral and peaty phase mineral substrates. The accumulation of organic material ranges from 20 to 40 cm in depth. This ecosite is commonly found in areas where the duration of flooding is short and the substrate is aerated by early to mid-summer. The ELC describes one mixed swamp type.

White cedar organic mixed swamp ecosite (SWM4)

This ecosite is comprised of white cedar, with black ash, yellow birch, white birch, red maple, hemlock, and balsam fir. The OIP manual (1985) describes substrates for this ecosite as organic (Of, Om, and Oh). The ELC describes one organic mixed swamp type.

Silvicultural guidelines are presented separately for eastern white cedar and eastern red cedar in the following.

EASTERN WHITE CEDAR

Changes since the presettlement era

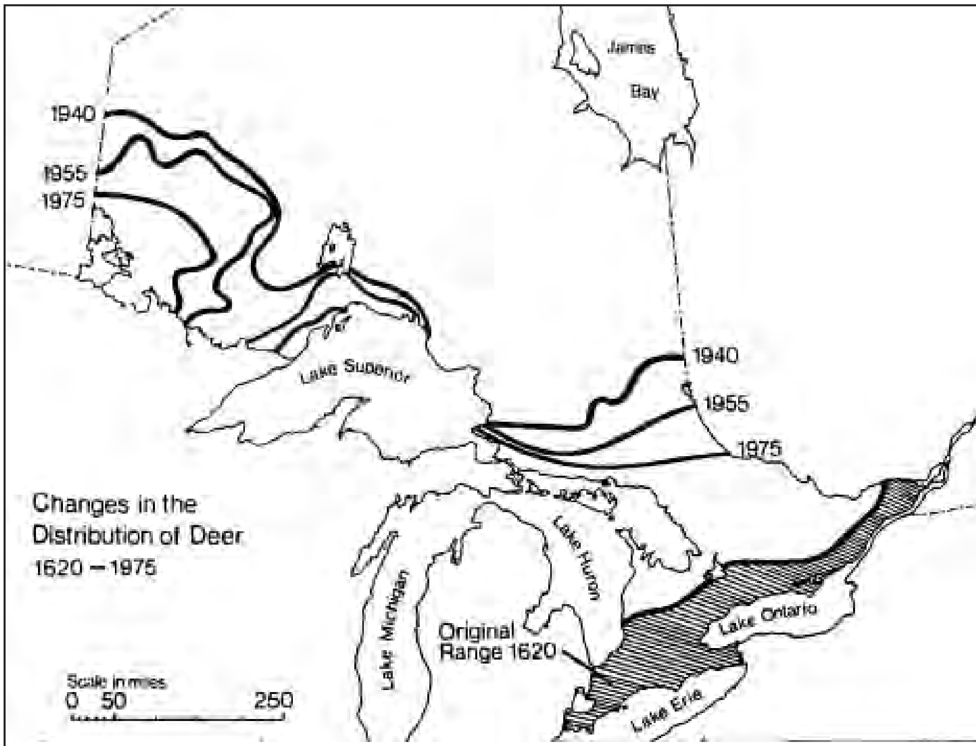
In Michigan, white cedar stands are believed to have originated when hot fires burned through swamps leaving pockets of seed trees, favorable seedbed conditions, and limited hardwood coppicing (Miller 1992). Furthermore, many mature stands in this state probably originated when deer browsing pressure was much lower (Van-Deelen *et al.* 1996).

Other studies in Michigan (Pregitzer 1991) suggest that the composition of cedar swamps today is somewhat similar to white cedar swamps of presettlement times, with a notable exception. Understory vegetation is different, largely due to heavy browsing by much larger and more widely distributed populations of white-tailed deer (**Figure 6.6.1**). Surveyors' notes in Michigan frequently mentioned cedar and hemlock undergrowth, now conspicuously absent from many stands (Pregitzer 1991). In addition, woody species unpalatable to deer have increased in many stands (Van-Deelen *et al.* 1996). Studies using fencing to eliminate deer browsing indicate that white cedar regeneration is seriously inhibited by deer densities as low as six deer per square mile (Sauer 1998).

Even-aged stands typically developed in large swamp openings following wildfire or clearcutting, or on abandoned upland fields where competition is not severe. Harvesting activities have helped to establish many second growth white cedar stands (Heitzmann *et al.* 1997). In Ontario, agricultural activities have also encouraged successful colonization and regeneration of white cedar in old fields and abandoned pastures.

Uneven-aged stands are usually associated with the later stages of succession and are generally found in swamps and moist sites. Normally, they develop through reproduction in

Figure 6.6.1: Changes in the distribution of deer from 1620-1975 (Smith and Borczon 1982)



small openings created by partial cutting or wind damage, particularly on more unproductive sites where vegetative reproduction is predominant (Johnston 1990). Uneven-aged stands also develop where white cedar gradually replaces its associates including balsam poplar, tamarack, black spruce, black ash, and trembling aspen. Without major disturbances such as harvesting or fire, eastern white cedar associations are very stable, as the species is very long-lived and only balsam fir is capable of regeneration in dense stands.

Choosing an appropriate silvicultural system

Appropriate silvicultural management of cedar stands depends on several factors including:

- an understanding of the autecology of the desired species
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed in the following.

Autecology of eastern white cedar

Some knowledge of the natural history of eastern white cedar can help to improve the likelihood of successful silvicultural management of forest types with a dominant white cedar component. Important biological information for white cedar (from Schaffer 1996 and Johnston 1990) is listed below and additional information is found in **Appendix B.**

Reproduction and early growth of eastern white cedar

a) *Seeds and germination*

- Good seed crops are produced every two to five years.
- Seed dispersal occurs in the fall, and has an effective range of only 40-60 m.
- Seedlings require bare substrate or moss mats or woody debris.
- Critical factors include constant moisture supply and warm temperatures.

b) *Site factors*

- On undisturbed sites, eastern white cedar regenerates best on decaying wood and logs (70 % of regeneration) because of improved microclimate, less litter and adequate moisture
- In disturbed areas, seedlings thrive in burned areas, probably because fire exposes mineral soil and improves moss beds as germinating sites. Fires must be severe however, to expose favorable mineral soil seedbeds. Skid roads with compressed moss beds that retain moisture are also suitable germination sites.
- Success of regeneration has been correlated to the number of hummocks in moist and wet stands (Chimner and Hart 1996). More hummocks improve regeneration success.

c) *Early growth*

- Early growth of eastern white cedar is slow.
- Best growth rates are obtained where trees are exposed to under one-half of full sunlight and plentiful moisture conditions.
- Although growth is best under full sunlight, partial shade is usually required to protect seedlings from drought and/or herbaceous competition.

d) *Other*

- Layering is also a common method of regeneration for eastern white cedar, particularly in lowland areas with sphagnum cover.
- Mortality in seedlings for the first year is generally very high and is commonly due to drought, smothering by sphagnum or logging slash, cutting and girdling by rodents, and deer browsing.

Reaction to competition

- Eastern white cedar is shade-tolerant with vegetative reproduction more tolerant than seedlings.
- It can withstand suppression for several years.

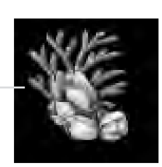
- It has the potential to respond well to release at nearly all ages.
- Response to thinning is variable. In Michigan, response to thinning in well-drained swamps was very favorable, but there was little to no response to thinning in poorly drained swamps. Thinning can result in increased risk of ice and snow damage for the first few years.

<u>Factors limiting growth and development</u>

- *Excessive moisture:* In wet areas, changes in drainage or water table levels can restrict root aeration and either restrict growth rates or cause mortality.
- *Shallow rooting habit:* The shallow rooting system of cedar makes it vulnerable to windthrow, a concern in partially cut stands with numerous edges. Shallow roots are also vulnerable to trampling, and damage from skidding and drought.
- *Ice and snow:* The dense foliage and weak wood of eastern white cedar makes it vulnerable to damage from ice and snow loading.
- *Fire:* Thin bark, high oil content and a shallow rooting system make it very susceptible to fire damage.
- Road salt harms white cedar.
- *Insects:* Carpenter ants and leafminers are the principal insect pests. Leafminers can cause scorching of foliage, and twig, and branch or tree mortality (Rose and Lindquist 1980) but most trees recover from an infestation.
- *Disease:* Few disease problems occur in natural stands. In the seedling stage, white cedar is susceptible to foliage blight fungi (*Phomopsis juniperovora* and *Didymascella thujina*). These fungi can cause some damage to foliage as the trees mature. Older trees are susceptible to butt rot (*Poria subacida, Tyromyces balsameus, Phaeolus schweinitzii*), with hollow butts being common in trees on knolls and other drier areas.
- *Browsing:* Winter browsing by deer on seedlings and saplings may cause severe damage and can even limit re-establishment on some sites. Approximate age of maximum browse production is 25- to 30-years-old. Even 15 to 20 % annual crown loss can cause mortality, and since cedar is a slow growing species, saplings can be exposed to browsing for extended periods of time. Other browsing herbivores include the snowshoe hare (which can be as damaging as deer), porcupines, and red squirrels which clip cone clusters.
- Harvesting operations can leave considerable amounts of slash on the ground that does not decompose readily. This slash may hamper re-establishment of seedlings.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.



Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands of eastern white cedar. Therefore managers must determine stand composition and structure, and current age-classes and condition of the stand. Also they must know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Cedar stands often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Tables 4.4.1**, briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

More than 46 species of birds, 33 mammals, and four herptile species use white cedar stands in Ontario to meet some of their seasonal needs for food and shelter (Schaffer 1996). Mature and older stands have been found to support the greatest species diversity (Doepker and Ozaga 1991), possibly due to the development of strata in the canopy and the presence of snags and down woody debris (Schaffer 1996). However, young and intermediate-aged cedar stands were preferred by some species, and a mixture of age classes in the landscape would benefit most wildlife (Doepker and Ozaga 1991). Other important wildlife features of white cedar stands include the provision of edge habitat (borders with other community types), riparian features, winter cover, and mast crops.

Eastern white cedar stands are important winter deeryards in many parts of southern Ontario because they provide thermal protection, hiding cover, preferred browse, and easier movement. In winter, once snow depths reach 25 to 35 cm, deer move into yarding areas, which typically are only 10 % of the size of the summer range (Schaffer 1996). Overlapping conifer branches trap snow, leaving less of it on the ground and create a more favorable microclimate by reducing wind speeds and maintaining higher and more stable humidity. Eastern white cedar is a favored browse species for deer and it is also the only native species in parts of Ontario that will maintain a deer in good health over the winter (Schaffer 1996).

The importance of white cedar stands to deer should be recognized in a management plan. Generally older stands provide the best cover for deer but younger stands provide better browse. Therefore provision of both is desirable. Management options discussed in this guide for white cedar generally benefit both timber and wildlife.

White cedar stands provide other natural heritage values as well. On some sites, cedar stands provide the shaded conditions required for species assemblages associated with seeps and cedar swamps. Some significant stands may also help to maintain local hydrological regimes, and cooler water temperatures of some riparian areas. Sometimes they support many interesting species, including numerous rare plant species. The globally rare orchid, the ram's-head lady's slipper can be quite common in some of the cedar stands found on the limestone plains of Site Region 6E. Undoubtedly a few stands support some very old specimens of this long-lived tree. Cedars growing on very shallow sites stabilize soil and provide cover on sites that might otherwise have no tree cover. Also cedar stands in parts of southern Ontario dominated by agricultural fields and urban landuse may function as locally important animal movement corridors.

Therefore, management of white cedar stands, especially the more mature stands, should take into consideration these other values, especially the distinct possibility of the presence of rare flora. Many plant species found in cedar swamps are very sensitive to logging, especially clearcut logging.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of cedar stands. The primary objectives for the management of most cedar stands will likely be for the production of commercially valuable building and fencing logs, posts, and shingles, as well as the provision of wildlife habitat.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood or clearcut silvicultural systems and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Another important consideration is available resources for management. In southern Ontario, the sustainable management of the majority of cedar stands for commercial purposes may be somewhat risky and not economically feasible for many landowners. It is likely to be an expensive and time-consuming process because of the difficulties associated with the natural regeneration of sufficient numbers of trees, the relatively slow growth rate of this species on many sites, and competition problems from other species. Long-term cost effectiveness becomes an issue if too many tending treatments are required to establish a second crop of trees. Also it could take many years for trees to reach merchantable sizes, especially on unproductive sites, and a long time for most cleared sites to regenerate cedar of commercial value.

Managing eastern white cedar stands

Three silvicultural systems are currently used in Ontario to manage cedar stands: shelterwood and clearcut in even-aged stands and group selection in uneven-aged stands.

Managing and regenerating even-aged stands

Once management objectives are determined, a stand prescription can be developed. **Table 6.6.1** describes a decision key for eastern white cedar management in Ontario. It was adapted from a review of the literature done by Shaffer (1996), and is based on research conducted in northern Michigan (Johnston 1977).

There has been some discussion about whether the clearcutting and shelterwood systems described below actually regenerate sufficient quantities of cedar (Heitzman *et al*. 1997). One of the main reasons treatments may have not worked in the past is because silvicultural guidelines were not followed correctly. Also cover strips have not been removed in a timely fashion. Often stands were harvested before the recommended entry age. Some stands were cut without controlling other species through preparatory or intermediate treatments (Doepker and Ozaga 1991). In order to help to ensure successful application of these systems, it is critical that recommendations be followed. The absence of fire may also contribute to lack of regeneration success. Even prescribed burns may not be hot enough to regenerate eastern white cedar.

To help choose the appropriate silvicultural options for a specific stand, the decision key shown in **Table 6.6.1** was developed. Decisions are based on site productivity, size of stand, species composition, and stand age. Follow the numbered decision points below until you reach a management option(s) in italics that best describes your site and stand conditions. When you reach a point in the key that no longer directs you to any subsequent points, go to the accompanying text description for further details on the management option in italics. For any point in the key further details are provided in the text.

Table 6.6.1: Decision key for eastern white cedar management in southern Ontario (modified from Schaffer 1996).

Text Description	Decision Factor	Continue to Point No.
1.	Unproductive sites (site index less than 8 m in 50 years) or site with significant conservation value: *leave alone*	
1.	Productive sites (site index greater than 8m in 50 years): manage stand .....……………………………………	2
2.	Stand area < 1 ha, or surveys indicate high value to wildlife: *manage primarily for wildlife*	
2.	Stand area > 1 ha, and surveys do not indicate high usage by wildlife: *manage for timber and wildlife*……………………. ………………………………………………………………..	3
3.	Stand is < 50 years: *do nothing*	
3.	Stand is immature (50- 80 years): *do intermediate treatment*	
3.	Stand is mature (80- 120+years): regenerate stand by appropriate silvicultural option………………………..	4
4.	Stand area 1- 4 ha: *regenerate stand by uniform shelterwood silvicultural system*	
4.	Stand area > 4 ha: regenerate stand by clearcut silvicultural system………………….…………………………	5
5.	Associated tree species abundant: *do preparatory treatment first or manage for other species*	
5.	Associated tree species are scarce………………………………………………………..……………...	6
6.	Stand area 4- 10 ha: regenerate stand by patch cutting…………………...………………………………..	7
6.	Stand area > 10 ha: regenerate stand by strip cutting……………………………………………..…………	7
7.	Residual cedar stems abundant (> 60 % stocking) …………………………………………………….…..	8
7.	Residual cedar stems scarce (< 60 % stocking)…………………………………………………………….…	10
8.	Presence of competing species (primarily hardwoods) is low……………………………………….…..…	9
8.	Cedar is a minor component of the stand: *manage for other species* OR …………………….……………..	5
9.	Most residual cedar < 50-years-old and in good health: *save residual stems*	
9.	Most residual cedar > 50-years-old, or in poor health: remove residual stems…………………….………	10
10.	Little slash cover … spread slash evenly, use natural seeding (planting if necessary)………………………….	11
10.	Much slash cover … broadcast burn slash, use natural seeding (planting if necessary)…………………..….	11
11.	After 4 years assess cedar reproduction and hardwood competition: if > 60 % and low competition, leave until 50 years………………………………………………………………… if > 60 % but high competition: control competition ………………………………………………………….. if < 60 % and low competition: supplement stocking by planting cedar seedlings……………………………………………………………………………………………………… if < 60 % and high competition: treat competition and plant cedar seedlings ..………………………………………………………………………………………	 3 11 11 11

1. Site productivity and management options

Eastern white cedar is found on a wide variety of sites in southern Ontario, from shallow to deep mineral, and organic soils. Growth rate varies according to site quality. For even-aged stands, a site index may provide a numerical expression of site quality. This index is based on the height in meters of the dominant and codominant trees in the stand, at a specified age (usually 50 years of age). In general, the growth rate of eastern white cedar ranges from less than 6 m on the least productive sites to at least 12 m on the most productive sites.

Other site and tree characteristics are useful indicators of site productivity, especially in uneven-aged stands where site indices do not apply.

The most productive sites tend to have

- dense stands of cedar with natural pruning of the crown to one-third of tree height, and
- widely-spaced annual rings, at least 2.3 mm apart (Johnston 1990).

Less productive sites tend to have

- wider spacing between trees, with several bare areas in the stand and crown cover extending to the ground, and
- narrow spacing between growth rings, less than 2.3mm (Johnston 1990).

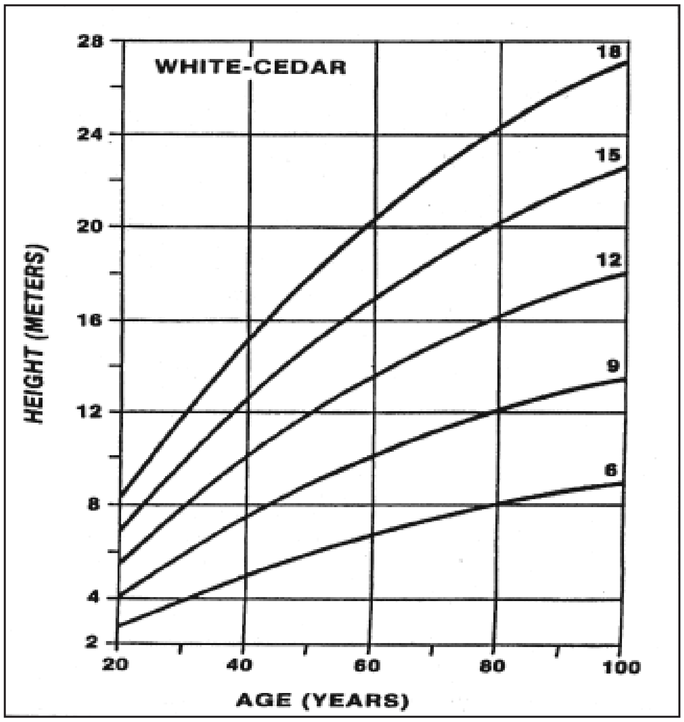
Figure 6.6.2 can also be used to provide an indication of site productivity. The heights and ages (by counting annual rings) of co-dominant and dominant trees in the stand can be compared to those corresponding values in **Figure 6.6.2**. Site index is indicated (in meters) at the top of each curve.

Little or no management is recommended for white cedar growing on unproductive sites (i.e., site index of 8 m or less in **Figure 6.6.2**) such as shallow mineral soils or wet or poorly-drained organic soils. Normally these stands only produce posts, and not sawlogs. If managed, the recommended silvicultural system is to clearcut in 20 m strips once the stand is mature, and to then spread the slash evenly on the ground to encourage natural seeding (Schaffer 1996). Intermediate cuts are not done.

Another option is to leave them alone for conservation purposes. These stands often help enhance water quality, stabilize soil, provide important deer browse, and provide cover on what might otherwise be a barren site. Slow-growing stands are often relatively older and rare plant species may have become established. Also harvesting activities on damper sites can have detrimental impacts (e.g., rutting, soil erosion, siltation of adjacent waterbodies) on wildlife habitat and sensitive features.

If it suits the landowner's objectives, more intensive management (all other options in the decision key) can be implemented on more productive sites (i.e., site index of at least 9 m in **Figure 6.6.2**).

Figure 6.6.2: Metric site index curves for eastern white cedar (from Laidly 1979).



2. Stand size and level of wildlife use

Small stands of approximately 1 ha that are heavily used by wildlife, might best be left to provide wildlife shelter and cover. Particularly in southern Ontario, such areas can provide critical deer shelter habitat where abundant browse exists in surrounding areas (Schaffer 1996). Ideal winter deer habitat has been described as clusters of three to four conifer trees (including cedar) with touching branches (Naylor 1999). To improve deer habitat within a stand, selected deciduous trees can be cut or girdled to encourage suckering and enhance the supply of hardwood browse.

Since small stands of cedar will not provide adequate browse for overwintering deer, it is important to provide browse from other sources, including surrounding deciduous stands, or adjacent agricultural lands (Schaffer 1996). Logging activities in adjacent stands, if timed when deer are in the area, can provide browse in the form of tree tops and coppice sprouts.

The silvicultural options outlined in subsequent steps will meet landowner objectives for both timber production and wildlife habitat provision.

3. Stand age and choice of silvicultural treatment(s)

Stands should be at least 50-years-old before any treatments are done.

Stands 50- to 80-years-old can benefit from tending prior to final harvest to either improve stand composition (i.e., remove undesirable species), increase timber growth, or enhance wildlife habitat to be provided by subsequent rotations. This work is referred to as an *intermediate treatment*, and in younger stands is usually precommercial in nature.

Intermediate treatment

Although white cedar is shade-tolerant, it still grows best under one-half to full sunlight conditions. Controlling overtopping competing trees can enhance growth rates, but the amount of control depends on management objectives. For multiple use stands, a mixed stand of 50 to 80 % cedar is probably ideal.

Schaffer (1996) recommends the following treatment for managing middle-aged stands (50 to 80-years-of-age) for timber production:

- Thin stands with a basal area of 44 m^2/ha (the average condition) to a residual basal area of 30 m^2/ha, by removing trees with poor form, trees with small crowns or crown dieback, diseased trees, and undesirable species. Release codominant and dominant trees in this and subsequent thinnings.
- Stands should be re-thinned every 10 years to at least 21 m^2/ha. If the objectives for the stand are to maintain existing white cedar composition, caution should be taken not to thin too heavily thereby promoting growth of competing hardwoods and shrubs. If competition is a problem on the site, thinnings should not reduce residual basal areas below 34 m^2/ha.
- These stocking levels should not affect volume accumulation or tree mortality, but will produce larger logs with more merchantable volume than many smaller logs.

Once the stand has reached maturity, typically at 80 to120 years, stand harvest and regeneration treatments are started. A discussion of appropriate harvesting and regeneration options follows.

4. Stand size and choice of silvicultural system

Small mature white cedar stands that are less then 4 ha in size are best managed using the uniform shelterwood system because use of patch or strip clearcutting would not leave enough residual trees to supply a source of seed to regenerate the next stand.

Uniform shelterwood system

With the uniform shelterwood system, a new stand is regenerated under a partial canopy of mature trees. The canopy is usually completely removed in a series of cuts.

1. The first cut (also known as a seed or regeneration cut) removes enough of the smaller diameter trees so that the residual basal area after cutting is 14 m^2/ha (Schaeffer 1996). Hence, the bigger crop trees are left to develop large crowns that will provide seeds and shade for successful regeneration of white cedar. Before cutting, it is important to select and mark the highest quality, codominant or dominant white cedar crop trees, based on their good potential for seed production, timber quality, and resistance to windthrow. Furthermore, since these crop trees will provide seed for natural regeneration, regeneration cuts should coincide with a good seed year whenever possible.
2. The second cut (also known as the removal cut) takes place once new cedar regeneration is well established beneath the mature trees, often approximately 10 years after the regeneration cut. Logging damage to regeneration can be minimized if the removal cut is done while the seedlings are still pliable (i.e., less than 3 m tall).

The benefits of properly applying the uniform shelterwood system include:

- prevention or suppression of the development of competing vegetation, particularly intolerant species such as aspen, white birch and raspberry
- a uniformly distributed seed source
- good germination and seedling survival because the partial canopy shading provided by the shelter trees prevents seedbed drying and seedling desiccation, and
- increase in size and value of shelter trees between the regeneration and removal cuts.

Stands with excessive numbers of undesirable species such as aspen or birch might benefit from a preparatory cut prior to the regeneration cut. This technique is discussed under point number "5. Associated species and preparatory cuts" which follows.

For stands greater than 4 ha, clearcutting is the recommended method of regeneration.

5. Associated species and preparatory cuts

When the proportion of associated tree species in the stand is high, a preparatory cut is recommended before any clearcutting. The proportion of associated species desired in a white cedar stand will depend on landowner objectives, but a goal of 50 to 80 % white cedar is recommended when managing for both timber and wildlife habitat (Schaffer 1996).

Preparatory treatment prior to clearcutting

To ensure that competing species are controlled, preparatory treatments should be completed at least five to 10 years before regeneration cutting is planned. To diminish survival of suckers, sprouts and seedlings from shade-intolerant competing species, it is important to maintain a residual basal area of 34 m^2/ha in desirable species (Schaffer 1996). It is usually more important to control hardwoods than conifers since many hardwood associate tree species on cedar ecosites readily reproduce both vegetatively and from seed. Also, associated conifer tree species on cedar ecosites provide winter shelter for deer and other animals, while most hardwood trees do not.

Once the stand is marked down to the residual basal area, the undesirable trees can either be felled if merchantable, or girdled or treated with herbicide if unmerchantable. Herbicide treatments may be the best choice for control of shade-tolerant species such as red maple since shade-tolerant sprouts and seedlings have the potential for release in thinned stands (Schaffer 1996). See **Section 8.1** for more information on vegetation management guidelines, including girdling and/or herbicide treatment options for polewood stems.

6. Regenerating stands by clearcutting

Once competing associated species have been controlled, and the stand has reached rotation age, the stand should be regenerated using the clearcut silvicultural system. Rotation age can be defined as the age of a stand when the mean annual growth of the primary timber species has reached its maximum. In other words, volume yield or sawlog yield per hectare has peaked, and will begin to decline through mortality and/or decay. Typical rotation ages for sites with varying productivity are shown in **Table 6.6.2**.

Table 6.6.2: Approximate rotation lengths (years) for sites with varying site productivity (from Johnston 1977).

Site Classification	Site Index (m)	Age for Opitimal Merchantable Volume (years)	Age for Optimal Sawlog Yield (years)	Age for optimum deer browse (years)	Age for optimum deer shelter (years)
Excellent	14	70-90	110-140	25-30	>60
Medium	11	80-100	130-160	30-40	>100
Poor	8	100-140	130-160	50-70	N/A

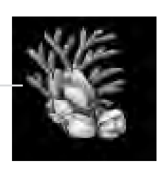
Both timber and wildlife considerations are best optimized if stands are managed to sawlog rotation age. Many years of optimum shelter can be provided as the trees mature.

Other factors may shorten the potential rotation age of a stand, including damaging agents of cedar such as windthrow, butt rot, and wind breakage (Schaffer 1996). If the stand is starting to decline from damaging agents, consideration should be given to accelerating harvesting and regeneration activities.

Two types of clearcut systems can be used to regenerate cedar stands once they have reached rotation age: *patch cuts* and *strip cuts*. Both of them depend on adjacent blocks of mature cedar to seed into the clearcut areas. On some sites, clearcutting could leave vigorous residual stems to become part of the regenerated stand (see point number “7. Managing residual stems in the clearcut system” which follows).

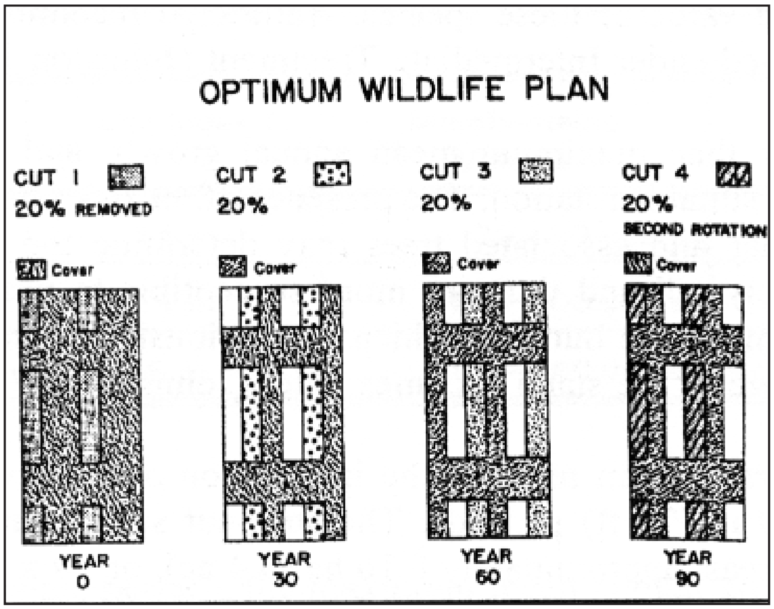
The patch cut system involves clearcutting blocks approximately 0.08 ha in size, which corresponds to a 30 m by 30 m block. The strip cut method involves clearcutting strips that are 20 m by 80 m or 0.16 ha in area. Patch cuts are generally recommended for stands 4 to10 ha in size, and strip cuts are recommended for stands greater than 10 ha in size. Patches and strips should be oriented perpendicular to the prevailing wind direction to maximize seed dispersal. No more than 30 % of a stand should be put into patches or strip cuts. The timing of each successive cut should be based on the success of regenerating cedar in the previous clearcuts; if there is little regeneration, additional cuts should not be created but rather the existing openings should be managed until the amount of regeneration is adequate (e.g., through supplemental planting). The final strips or patches in a stand are not clearcut but managed with the two-cut shelterwood system (described earlier) to ensure that a mature seed source for these strips remains (Schaffer 1996).

Managers may have to consider supplementing natural regeneration with plantings if stocking surveys indicate inadequate numbers of natural seedlings. If planting is required, seedlings should be obtained from a seed zone as close as possible to that of the planting site (**Figure 4.1.4**).



When using patch and strip cuts, the management objective is to regenerate even-aged blocks of cedar. The pattern of orienting blocks influences wildlife use, and patterns have been designed to optimize deer use (**Figure 6.6.3**). Ideally a stand will be converted to five age classes each separated by 10 to 20 years. This will maximize structural and age class diversity ensuring both browse and winter cover availability in a small area.

Figure 6.6.3: A proposed design for orienting strip cuts in cedar stands (from Smith and Borczon 1981).



Young cedar stands regenerated in clearcut blocks are susceptible to over-browsing by deer or snowshoe hare. Options for controlling browsing include providing alternative food sources such as agricultural crops far from managed stands, increasing hunting pressure, fencing, and use of tree protectors or repellants to protect seedlings and improve their growth rates. Many of these options may not be affordable, practical or effective, and the best solution may be to promote abundant regeneration on all cut areas, and to distribute cutover areas across the landscape (Schaffer 1996).

7 and 9. Managing residual stems in the clearcut system

Residual stems are trees that are left during the clearcut operation and are generally less than 50-years-old with well-developed crowns. Residual stems should be left for stand reproduction if they are abundant on the site (i.e., 60 % or more of 2 m by 2 m sampling areas contain one young and healthy cedar), and the effort to retain stems is less than that required to establish new regeneration (Schaffer 1996).

Retaining residual stems requires careful harvesting practices and slash removal from the site so that they will not be damaged.

8. Controlling competing tree species on newly established sites

Residual stems of associated tree species should be controlled when they suppress residual cedar stems or seedlings. Undesirable trees can be felled if they will provide deer browse, otherwise they can be girdled. If hardwoods are a serious problem, they may have to be treated with herbicide, particularly species such as aspen that reproduce mainly from suckers and sprouts (**Section 8.1**).

10. Managing slash cover

Slash cover may create a problem for regenerating cedar because it can bury residual stems and seedbeds. A heavy cover of slash is detrimental but a light cover is usually beneficial because it can prevent seedbeds from drying out (Schaffer 1996). Two methods of slash disposal are commonly used: broadcast burning and full-tree skidding.

Broadcast burning is the preferred method because it eliminates most slash; kills residual conifers; sets back competing hardwoods, shrubs and some herbaceous vegetation; and improves seedbed conditions by exposing mineral soil. It is best utilized in larger cut blocks. Broadcast burning is not recommended in small patch and strip cuts, and is inappropriate for use in the shelterwood system (Schaffer 1996).

Although it is not recommended for use in other forest cover types, in cedar stands, full-tree skidding in winter is probably the best choice for many landowners in southern Ontario as the cost is generally lower than that for broadcast burning, and it can be safely done in small areas. Entire trees are skidded to a delimbing area, limbed, and then taken to a landing for bucking and sorting. Skidding could be delayed for several days after the trees are felled to provide browse for deer (Schaffer 1996). To minimize site and stand damage, use the guidelines for careful harvesting provided in **Section 8.3**.

11. Assessing the success of silvicultural operations

It is important to evaluate the success of regeneration following silvicultural treatments because natural seeding may fail, or competition might become a greater problem than initially anticipated. Both trembling aspen, white birch, and gray birch will seed into burned seedbeds and seedbeds prepared by full-tree skidding. Herbicide treatments or other vegetation management techniques may be necessary to release cedar seedlings from competing vegetation (Schaffer 1996).

If natural seeding is poor, planting may be necessary to increase stocking levels. Planting is most successful on sites with at least 30 cm soil depth. Bare root transplant stock (e.g., 1 ½ + 1 ½[1]) should be chosen and planted at 2 m by 2 m spacing on better sites, or at 1.5 m by 1.5 m spacing on less productive sites. These tight spacings should encourage good height growth and tree form, natural pruning, and allow for some mortality. Larger spacings may promote multiple stems and reduce future merchantable timber (Schaffer 1996).

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[1] These numbers refer to the years that seedlings were grown in the nursery (i.e., 1 ½ years in a shaded seedling bed) and then transplanted, at a wider spacing, to grow a further 1 ½ years in a transplant bed.

Managing and regenerating uneven-aged stands

Two options exist for managing uneven-aged stands: maintaining the stand as uneven-aged or converting it to an even-aged stand. The choice depends on the landowner objectives and stand conditions.

Convert to an even-aged stand

Conversion to an even-aged stand may be the best option if:

- the proportion of cedar in a stand is declining
- the quality of the stand is declining through dieback, butt rot, ice storm damage, or other damaging agents, or
- the stand contains many less desirable timber species such as aspen or white birch.

To convert a stand using even-aged management, see the decision key outlined in **Table 6.6.2**. Use the codominant and dominant trees in the stand when making decisions on the basis of stand age. The option of managing residual trees must also be carefully considered. High quality residuals should be retained. Low quality residuals should be felled or girdled.

Manage as an uneven-aged stand

If an uneven-aged stand is doing well on a site and producing high quality sawlogs and deer habitat, the best option is to continue managing it as an uneven-aged stand.

Uneven-aged stands can be managed as more permanent deer cover since a semi-continuous crown is maintained. They can also be managed to provide old growth or for other natural heritage and conservation values, especially on smaller or unproductive sites.

Uneven-aged management can be accomplished with either the group selection or the single-tree selection systems.

Group selection system

The group selection system is based on cutting small openings in the stand, resulting in small pockets of seedlings and scattered pockets of different age classes. Refer to **Section 6.1** of this guide for more detailed information on the group selection system, but consider the following more specific guidelines specific to promoting white cedar regeneration in the openings (from OMNR 1998*b*).

- Choose suitable areas to create openings such as pockets of trees with poor form or quality (that will be removed), downwind from suitable seed sources.
- Maximum size of a group opening is the stand height.
- Group openings should be uniformly distributed over the stand.
- Group openings should not cover more than 20 % of the stand at each cut time.
- The return cycle between cuts is 15 to 20 years.
- On upland sites, log in the late summer when soil is dry enough to create soil disturbance

and improve seedbed conditions for white cedar germination. In swamps, winter logging on frozen ground is preferable to avoid excessive site damage.

- Large numbers of undesirable species may need to be controlled prior to creating openings for natural seeding (see discussion of preparatory cuts in previous even-aged management section).

Single-tree selection system

The single-tree selection system is based on removing individual trees, and the subsequent utilization of their growing space by shade-tolerant-regenerating tree seedlings (OMNR 1998*b*). The single-tree selection system is probably most appropriate where the management goal is to provide continuous canopy cover in the stand (e.g., for provision of wildlife habitat such as deeryard).

To implement the single-tree selection system in an uneven-aged stand, use the following guidelines summarized by Schaffer (1996).

- Remove trees singly or in groups of two or three.
- Remove trees with poor form, such as trees declining from damaging agents, or less desirable species in the stand.
- Use a cutting cycle of 15 to 20 years.
- A residual basal area of 26.4 m^2/ha on a five-year cutting cycle in a mixed cedar stand was found to produce the most white cedar regeneration in Maine (Brissette 1996). This system emphasized harvesting tree mortality and improving stand quality and species composition. Single-tree selection cuts that left residual basal areas of 23 and 18.4 m^2/ha had much less cedar regeneration. This five-year cutting cycle system is not commonly used in Ontario because it requires too much management.

Changes since the presettlement era

Eastern red cedar is probably much more prevalent in southern Ontario than it was during the presettlement era. Land clearing and grazing have promoted its distribution across much of central and eastern Ontario, by providing suitable seedbeds and limiting competition. In presettlement times red cedar may have been a common pioneer species on burnt, dry sites. In Point Pelee National Park fire is being evaluated as a tool to regenerate eastern red cedar stands (Falkenberg *et al*. 1999).

Choosing an appropriate silvicultural system

Appropriate silvicultural management of cedar stands depends on several factors including:

- an understanding of the autecology of the desired species
- the current stand composition, structure, and condition
- site potential or capability
- wildlife habitat and other natural heritage values

These factors are briefly discussed in the following.

Autecology of eastern red cedar

Some knowledge of the natural history of eastern red cedar can help to improve the likelihood of successful silvicultural management of forest types with a dominant red cedar component. Important biological information for red cedar is listed in the following text.

<u>Reproduction and early growth of eastern red cedar</u> (Williamson 1957)

a) *Seeds and germination*

- Good seed crops are produced every two to three years.
- Seeds are dispersed almost entirely by birds and mammals including grouse, pheasant, and turkey that feed on the fruit in the winter.
- Most germination of seed occurs in the second spring after dispersal.

b) *Site factors*

- Preferred seedbed is moist loam soil that is somewhat calcareous.
- Most growth in the first year establishes a long root system.
- Red cedar is well adapted to survive and thrive in drier environments including the limestone plains of eastern Ontario. It can retain water and sustain stomatal openings at low water potential (Lawson 1990). Seedlings are drought hardy partially because of a long tap root and small leaf area.

c) Early growth

- Seedlings are shade-intolerant, only thriving in ample sunlight.
- Seedlings are resistant to most diseases, however young seedlings are occasionally damaged by mice or rabbits.

<u>Reaction to competition</u> (Williamson 1957)

- Red cedar is considered to be shade-intolerant. On thin dry soils, red cedar can compete with hardwoods, but hardwoods usually replace cedar on better sites. Some individuals have been observed to live for decades under a closed canopy of hardwoods (Lawson 1990).

- Red cedar is a pioneer species that invades old fields and pastures (Lawson 1990). In the central states, these pioneer stands usually begin to deteriorate after 60 years, when hardwoods have become established and can predominate on the site. The role of red cedar in Ontario may be similar (i.e., as a nurse crop for other species including bur oak, white spruce, and bitternut and shagbark hickory).

<u>Factors limiting growth and development</u>

- *Fire:* Fire is the greatest threat to red cedar; even the lightest surface fires injure its thin bark and shallow root system.
- *Insects:* Red cedar has few insect problems but is occasionally damaged by boring insects and bagworms.
- *Diseases:* Red cedar is the intermediate host for apple-cedar rust that damages apples and hawthorns but does little harm to red cedar. Seedling roots are susceptible to damage from nematodes and grubs (Lawson 1990). When weakened by stress or insects, red cedar is susceptible to root rot fungus (*Heterobasidion annosum*).
- *Browse:* When food is scarce, deer will browse heavily on red cedar.

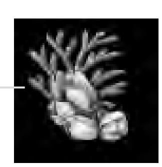
Current stand composition, structure, and condition

Red cedar is typically found in even-aged stands as a pioneer species in old fields and pastures. It is less commonly found as a component of hardwood stands, or associated with white spruce (Lawson 1990).

Wildife habitat and other natural heritage values

Eastern red cedar stands provide several types of wildlife habitat including:

- good nesting and roosting cover for many birds (including the endangered loggerhead shrike)
- forage for small mammals and birds. Fruits are high in crude fat and fiber and are eaten by many species including waxwings, bobwhite, ruffed grouse, pheasant, wild turkeys, rabbits, foxes, raccoons, skunks, opossums and coyotes. It is sole larval food plant of the provincially rare olive hairstreak butterfly
- winter thermal cover



- escape cover for small mammals and possibly deer, and also emergency browse
- animal movement corridors across open landscapes.

Stand potential or capability

The majority of eastern red cedar stands in Ontario are quite young and it is unknown if any will reach their full potential. In the United States, mature trees are typically 12 to 15 m tall with a diameter of 30 to 60 cm. Specimens have been observed to reach 35 m in height or more and diameters greater than 120 cm. It is likely that red cedar in Ontario will start to decline long before it reaches this size, and it may best serve as a nurse crop in old fields and pastures to establish white spruce or hardwoods.

Management of eastern red cedar stands

Studies in Arkansas have shown that red cedar is best managed in even-aged stands (Lawson 1990). Three options are recommended for managing red cedar stands in southern Ontario. These include:

1. using red cedar as a nurse crop to establish a hardwood forest
2. crop-tree management to optimize red cedar growth for forest products
3. converting the stand back to an old field or rough pasture for wildlife habitat.

If the olive hairstreak butterfly is recorded for the stand, professional advice should be sought on management options.

1. Eastern red cedar as a shelterwood for other species

Eastern red cedar can be used as a nurse crop to provide shade and moisture conditions necessary for hardwood regeneration. Red cedar is then removed using the shelterwood system, once hardwood regeneration is well established. When promoting regeneration of hardwoods under a red cedar canopy, grazing must be discontinued, as cattle, which do not eat red cedar, will readily consume seedlings of other species. On some sites it may require many years after grazing is curtailed for sites to recover from the detrimental soil compaction effects of this activity, and for site conditions amenable for germination of other species to improve.

Under the shelterwood system, the nurse crop of red cedar should be allowed to continue growing until a good component of hardwood (or white spruce) regeneration has become established. If the red cedar is dense and allowing little regeneration of other species, it may have to be thinned in a preparatory cut. Once the hardwood regeneration is well established, one-half of the red cedar could be removed to open up the canopy and promote regeneration of other species. The remaining red cedar would continue providing sheltered conditions amenable for regenerating other species. Then it could either be removed once the regeneration has overtopped it, or left as a minor component of the stand to decline naturally.

2. Crop-tree management to optimize red cedar growth

A second option for management is to manage the stand for red cedar products. Williamson (1957) found that growth in open or understocked stands on above average sites in the Ozark region of Arkansas was approximately twice that of overstocked stands (0.81 cm in 10 years vs. 0.38 cm in 10 years). Growth can stagnate in pure stands of red cedar as it does not thin itself out naturally (Williamson 1957). Therefore, tree spacing should be regulated so that this does not happen. No mention is made of an appropriate spacing however, and the ideal density for growing sawlogs is unknown (Lawson 1990). A method that could be tried in young stands is crop-tree release. The best 250 to 300 crop trees/ha (100 to 120 crop trees/acre) could be identified, and then released on two or three sides to maximize growth.

In Arkansas, the greatest mean diameter-growth occurred with 125 crop trees/ha (50 crop trees/acre). Care should be taken not to thin too much however, as excessive thinning promotes excessive formation of sapwood (not as valuable) and growth of lower branches (Lawson 1990).

3. Converting the stand back to an old field

A third option involves converting the stand back to an old field, an unimproved pasture, or a rare, non-forested natural community (e.g., alvar, prairie or savannah) for wildlife habitat or conservation purposes. This option has little to do with silviculture and will only be discussed briefly. For further information consult the Extension Note: *Management Options for Abandoned Farm Fields*.

One option that is worth mentioning for eastern Ontario is the conversion of red cedar stands to old fields or pasture in order to provide habitat for the endangered loggerhead shrike. To do this, use the following guidelines (C. Grooms, consulting biologist, personal communication, 1999):

- leave individual red cedars scattered throughout the area, preferably one or two trees every 50 m
- leave some tall deciduous trees for lookout perches
- leave a variety of shapes and sizes of red cedar to provide vertical and horizontal habitat structure
- leave any hawthorn shrubs uncut
- clear any spreading juniper and prickly ash.

Eastern red cedar stands can be controlled by cutting or burning. Controlled burning is used to control the species on active pastures in the United States (Lawson 1990).

6.7 HEMLOCK

by Peter and Erin Neave and David Bland

T. Haxton

Introduction

Eastern hemlock often grows on dry, shallow tills, interspersed with wet swamps; on north- and northwest-facing shallow rocky slopes; and on wet, sandy swamp borders. It is also found in coves and cool moist valleys. It grows in coniferous and mixed forest stands, and occurs on a wide range of soil textures including sands, loams, and clays, primarily in the moist to fresh moisture regimes. In coniferous stands, it is typically found on coarser, acidic soils. In Site Region 6E it occurs on shallow and deep soils; in Site Region 7E it is found on deep soils. It is more widespread in eastern Ontario. Typical associated species include white pine, eastern white cedar, red maple, and yellow birch.

Eastern hemlock can form a dense canopy and together with its acidic litter, can restrict the growth of understory vegetation. Although it is the most shade-tolerant tree species in southern Ontario and can become established in as little as five per cent sunlight, it responds poorly to any significant canopy disturbance that allows other species such as sugar maple, beech, and red spruce to gain dominance. It also has a shallow root system that makes it sensitive to disturbance and drought, and no ability to resprout.

Hemlock has sensitive requirements for regeneration. It does best in shade, often germinating on rotten stumps, logs, or mounds that are warmer and moister than litter or mineral soil. Frequently it regenerates under white pine or sugar maple. However browsing deer often destroy regeneration. This species grows slowly and is very tolerant of competition. It may become part of a climax community on some north-facing upland sites as it easily survives under its own canopy. It can also become codominant in a hardwood stand.

Fresh-moist hemlock coniferous forest ecosite (FOC3)

This ecosite if usually found on sites with soil texture varying from sands to coarse and fine loams, with some finer silt and clay components. Soil moisture regime ranges from fresh (MR 2,3) to moist (MR4-6); drainage is classed as well (DR3) to imperfect (DR 5). It is generally found in cooler areas, such as middle to lower slopes with northern exposure, seepage areas, and bottomland topographic positions. Often the water table is high and the microtopography is complex.

The ELC describes one vegetation type for this ecosite. The fresh-moist hemlock coniferous forest type is typically found on coarser acidic soils. It occurs sporadically throughout Site Regions 6E and 7E but is most common in the northern parts of Site Region 6E.

Dominant Trees	hemlock dominated with white pine, balsam fir, and white cedar
Less Common Associates	sugar maple, green ash, and white birch
Common Shrubs	beaked hazelnut and maple leaf viburnum
Common Herbs and Ferns	wild sarsaparilla, Canada mayflower, foamflower, bluebead lily, starflower, goldthread; wood ferns; ferns species are often numerous
Soil Moisture Regime	moist (MR 4-6) to fresh (MR 2-3)
Soil Drainage	well-drained (DR 3) to imperfect (DR 5)
Equivalent Ecosite in Central Ontario	ES30 (Chambers *et al.* 1997)

Fresh-moist hemlock mixed forest ecosite (FOM6)

This forest ecosite is found on sands, loams, and sometimes clays. It is found on lower to mid-slope, and bottomland topographic positions, as well as in seepage areas.

There are two vegetation types associated with this ecosite. The fresh-moist sugar maple-hemlock mixed forest type is typically found on soils with a fresh moisture regime (MR 1-3). This forest type is common in Site Region 6E but in Site Region 7E, it is restricted to sites with cooler than normal microclimates. The fresh-moist hemlock-hardwood mixed forest type is typically found on soils with a moist soil moisture regime (MR 4-6). It is infrequently encountered in Site Region 6E, being most common in the northern part of this region. It is rare in Site Region 7E.

Dominant Trees	eastern hemlock, sugar maple, and yellow birch
Less Common Associates	red maple, white birch, beech, black ash, and eastern white cedar
Common Shrubs	riverbank grape, maple leaf viburnum, and beaked hazelnut
Common Herbs and Ferns	trillium, wild sarsaparilla, and red baneberry
Soil Moisture Regime	moist (MR 4-6) to very fresh (MR 3)
Soil Drainage	well-drained (DR 3) to very poorly drained (DR 7)
Equivalent Ecosite in Central Ontario	ES30, 28 (Chambers *et al.* 1997)

Changes since the presettlement era

The prevalence of eastern hemlock in northern hardwood forests, including those of southern Ontario, has likely declined since settlement (Frelich 1995). During the late 19th century, Europeans logged most areas where it was found. The bark was used extensively for the tanning industry (Elliott 1998) and the wood was used for framing, sheathing, sub-flooring, and crating (Quimby 1996). Regeneration of hemlock was often poor, probably due to its inability to compete with sugar maple and beech. In some areas, extensive cutovers resulted in an unsuitable microclimate for hemlock seedlings, leading to a further decline in the distribution of this species (Davis *et al.* 1996). More recently, heavy browsing by white-tailed deer have further limited the re-establishment of hemlock. Enclosure studies using fencing to eliminate

deer browsing indicate that deer densities as low as six deer per square mile seriously inhibit the growth and regeneration of this species (Sauer 1998).

Some hemlock has persisted due largely to its longevity, ability to remain suppressed in the understory for years, and the market preference for hardwoods during the 1900s (Foster *et al.* 1992). Many of the seedlings and saplings that were released when the canopy old-growth trees were cut for tannin are now polewood or mature trees (Quimby 1996). In some areas its location on steep rocky slopes made economical removal difficult.

Choosing an appropriate silvicultural system

Selection of the most appropriate silvicultural system for the management of hemlock stands and/or clumps of hemlock within other stands depends on several factors:

- an understanding of the autecology of hemlock
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed in the following.

Autecology of hemlock

Some knowledge of the autecology of eastern hemlock can help to improve the likelihood of successful silvicultural management of forest types with a dominant component of this species. Important biological information for hemlock is listed below and additional information is provided in **Appendix B**.

<u>Reproduction and early growth of hemlock</u> (Anderson 1994*a*; Godman and Lancaster 1990; Collins 1990)

a) *Seeds and germination*
  - Seed crops occur every two to three years.
  - Cones mature in the fall and the seeds are dispersed by wind over the snow throughout the winter.
  - Viability of seed is low.

b) *Site factors*
  - Germination and early survival are best on cool moist sites, and favorable seedbeds include moist well-decomposed litter, rotted wood and moss mats. Mixed mineral soil and humus are the best substrate for survival and growth. Full sunlight and dark-colored mediums promote poor survival due to desiccation and/or heat stress.
  - In managed sites, seedbeds must be prepared for successful regeneration either through mixing organic material and mineral soil, or through prescribed fire to expose a partially decomposed layer. Without these conditions, most regeneration is limited to rotten logs, stumps and mounds that have a warmer surface and better moisture retention than the forest floor.

- Survival of hemlock seedlings is greater in habitats with shallower litter, more coniferous litter, and less woody debris**.** Hemlock seems unable to establish itself on hardwood litter, but can establish on the pit and mound topography found in moist hardwood stands. Windthrown root balls will eventually disintegrate into mounds of mineral soil ideal for hemlock germination.

c) *Early growth*

- Slow growing seedlings may be smothered by hardwood litter, particularly litter of sugar maple.
- Hemlock is extremely shade-tolerant and can become established in as little as five percent sunlight.
- Saplings growing in deep shade can be 2.5 cm DBH at 100-years-of-age
- While hemlock can survive in low levels of sunlight, it is also easily released from overhead competition.
- Hemlock establishment is associated with years of regular, adequate precipitation.

Reaction to competition (Anderson 1994*a*; Godman and Lancaster 1990)

a) Hemlock is the most shade-tolerant of all species because:

- The needles of its crown are concentrated on the ends of the branches and need only 2 % of full sunlight to live.
- Light saturation levels in mono-layered crown species such as hemlock show a rapid rise in photosynthesis from 2- 15 % of full sunlight; multi-layered crowns do not respond to these low light levels.
- Hemlock has a high root/shoot ratio. It is capable of high rates of root biomass production, even at low light levels. For example, it is 10 times more efficient than jack pine.

b) Hemlock is well adapted to respond to release from competition (i.e., increased light levels). The degree of response is related to the active crown size. Trees with live crown ratios greater than 50 % respond quickly; those with less than 30 % respond much more slowly. Individuals are capable of surviving suppression for up to 400 years, and dramatic growth releases (up to 8.8 mm/yr) have been recorded in some older trees (Abrams and Orwig 1996). However, excessive release can damage hemlock, reducing growth rates or causing mortality through windthrow.

c) Hemlock is adapted to cool environments such as north-facing slopes and sheltered valleys where it may be able to compete better. Net photosynthesis of hemlock is optimal between 14 and 19 ^{O}C.

d) Hemlock is sensitive to disturbance and does not compete as well with other shade-tolerant species such as sugar maple and beech. These other species are adapted to disturbance since they have less vigorous requirements for establishment, the ability to resprout, deeper root systems (sugar maple and beech), and are not as palatable to deer and other herbivores.

Factors limiting growth and development (Anderson 1994*a*; Godman and Lancaster 1990)

- Hemlock seeds are susceptible to mold damage, and damping off fungi, and root rots kill many seedlings. Several rusts affect the foliage and cone production.
- Few insects cause damage of economic importance; one exception is the hemlock borer that attacks weakened trees. Spruce budworm can defoliate hemlock if all of the balsam fir in the area have already been utilized. The hemlock looper causes foliage damage by eating part of the needle that then dies back. The hemlock wooly adelgid is increasingly infesting hemlock in the United States. Symptoms include poor crown condition and sharply reduced terminal branch growth (Souto *et al.* 1996).
- White-tailed deer readily browse hemlock, often eliminating patches of regeneration. Snowshoe hare and eastern cottontail frequently browse hemlock, and mice, voles, squirrels, and other rodents eat the seeds. Porcupines sometimes remove the bark at the top of larger trees, causing serious wounds and/or topkill. Sapsuckers are associated with ring shake problems in some areas.
- Hemlock seedlings and saplings are vulnerable to fire, however the thick bark of older trees allows them to resist light fire damage. Burns are often beneficial in re-establishing hemlock on a site.
- Heavy cutting in a stand predisposes hemlock to windthrow.
- Light cutting may promote radial stress cracks and ring shake in older trees, severely reducing their value for timber.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.

Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands. Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Hemlock stands often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Hemlock stands are considered essential for white-tailed deer in winter. These trees intercept snow well and moderate the local microclimate. With less snow on the ground, deer can move about more easily and they stay warmer than they do in more open habitats. However, deer numbers will have a significant impact on any plan to regenerate hemlock and this factor must be taken into account (Anderson 1994*a*). In contrast, sugar maple often resprouts fast enough to compensate for repeated browsing (Davis *et al.* 1996) and beech is relatively unpalatable (Runkle 1985).

Hemlock stands provide important winter cover for numerous other species such as ruffed grouse, wild turkey, and small mammals. Large trees provide roosts for wild turkeys and some raptors during winter, especially if they are close to foraging areas. In some parts of southern Ontario, hemlock stands and stands in which hemlock forms a dominant component have significant natural heritage value because they are an uncommon or even rare forest cover type. Therefore in these areas, management activities should not lead to an overall decrease in their area or representation within the larger region.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of hemlock stands.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood silvicultural system and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Managing hemlock stands

In general, managers should encourage the retention of hemlock, due to its reduced abundance and regeneration as compared to it historical presence. Depending on landowner objectives, hemlock could be re-introduced to areas where it was mostly eliminated through harvesting and has not recovered. It could be established in pockets by encouraging natural seeding or by planting seedlings. Refer to the ecosite descriptions for typical site conditions on which hemlock will thrive.

Hemlock is found in both even-aged and uneven-aged stands. It can be found in almost pure stands, or can be a minor component of hardwood stands. Typical even-aged associations tend to have white pine or sugar maple in the canopy, with hemlock in the understory to mid-canopy, and all trees are of similar age. These stands with stratified canopies can have better growth rates than pure hardwood stands, or pure hemlock stands. The stratified canopy appears to boost production as measured by basal area and biomass yield (Kelty 1989). Even-aged stands of pure hemlock are unusual, although stands of similar-sized trees do occur (Anderson *et. al* 1990).

Both even- and uneven-aged management systems can be successfully used to manage hemlock, but the even-aged system has had more success (Godman and Lancaster 1990).

However, clearcutting is not recommended as is it has been shown to result in the virtual elimination of hemlock from the overstory of stands after 46 years (Hix and Barnes (1984) as cited in Anderson 1994*a*). Without fire disturbance, hemlock will not regenerate naturally following clearcutting.

Managing even-aged stands of hemlock

Hemlock is part of the Tolerant Hardwood Working Group (THWG), and a considerable amount of silvicultural research has been done on it and its associates. A recommended treatment key has been developed for the THWG (Anderson *et al.* 1990) and it is presented in simplified format, focusing on hemlock and its associates (**Table 6.7.1**).

The term "overstory has potential for future development" is defined as an overstory comprised of stems that will improve in log quality and maintain growth and tree vigor over time. Stands with the majority of canopy trees exhibiting dieback at the top of the crown, excessive stem damage from previous logging activities, or overmature canopies of short-lived species such as aspen or white birch do not have potential for future development. Small proportions of trees in the overstory with little potential for future development are acceptable, as these stems can be removed through improvement cutting.

The decision key shown in **Table 6.7.1** was developed to help to select the most appropriate silvicultural options for a specific stand. Decisions are based on size of hemlock stems and its canopy position and stocking. Improvement cuttings should be light and remove no more than one-third of the stand's basal area (Eyre and Zillgitt 1953). Follow the numbered decision points to reach a management option (in italics) that best describes the site and stand conditions. Then read the accompanying description for further details on the management option.

1. Hemlock size in the stand

Management options in this decision key are based on the average diameter of hemlock in the stand. It is assumed that hemlock is either one of the dominant trees in the stand or is at least the dominant species in the understory.

2. Overstory presence and growth of seedling- or sapling-size hemlock

If seedling and sapling stands of hemlock do not have an overstory, the recommended management is to allow them to grow until the average diameter of dominant hemlock in the canopy is at least 9 cm in diameter. At this point the stand should be re-assessed.

3. Stocking of overstory with seedling- and sapling-size hemlock

If the seedling- and sapling-sized hemlock understory has an overstory, management is based on the density or stocking of the overstory.

Overstories with a density less then 9 m^2/ha of trees 24 cm DBH or larger are open enough to permit good hemlock growth in the understory. In this case, the silvicultural prescription is to wait and allow the dominant hemlock in the understory to reach a minimum size of 9 cm DBH and then re-assess the stand.

Table 6.7.1: Decision key for managing even-aged hemlock stands (adapted from Anderson 1994*a*).

Text Description	Decision Factor	Continue to Point No.
1.	Hemlock size is:	
	Seedling and sapling (0-9 cm DBH)	2
	Polewood (9-24 cm DBH)	7
	Sawlog (> 24 cm DBH)	9
2.	Is an overstory present?	
	No: *wait until average understory dominant reaches polewood size*	
	Yes:	3
3.	Stocking of stems >24 cm DBH in the overstory is:	
	< 9 m^2/ha: *wait until average understory dominant reaches polewood size*	
	> 9 m^2/ha	4
4.	Overstory has potential for future development?	
	Yes	5
	No	6
5.	Stocking of overstory stems >24 cm DBH is:	
	> 24 m^2/ha: *reduce stocking by one-third through improvement cutting*	
	> 16 m^2/ha: *reduce stocking to 16m^2/ha by improvement cutting*	
	between 9 to 16 m^2/ha: *apply light improvement cutting only where necessary*	
6.	Stocking of overstory stems > 24 cm DBH is:	
	> 24 m^2/ha: *reduce basal area by one-third through improvement cutting*	
	> 16 m^2/ha: *reduce to 16 m^2/ha through improvement cutting*	
	between 9 to 16 m^2/ha: *do nothing now, review when stocking > 16 m^2/ha.*	
7.	Is an overstory present in polewood hemlock stand?	
	No: *apply crop-tree release and thinning*	
	Yes:	8
8.	Does the overstory have potential for future development?	
	Yes: *apply crop-tree release and thinning to polewood and improvement cutting in the overstory*	
	No: *remove overstory and apply crop-tree release via thinning to polewood stems*	
9.	Do the sawlog hemlock stems have potential for future development?	
	Yes: *apply selection system*	
	No:	10
10	Regeneration in the understory of the sawlog hemlock canopy is:	
	not satisfactory: *regenerate hemlock with the uniform shelterwood system*	
	satisfactory:	11
11.	Allow understory to grow. If overstory stocking of hemlock stems > 24 cm DBH is:	
	> 24 m^2/ha: *reduce basal area by one-third*	
	> 16 m^2/ha: *reduce to 16 m^2/ha.*	
	< 16 m^2/ha: *do nothing, review if stocking becomes > 16 m^2/ha*	

4. and 5. Stocking and vigor potential of overstory

Overstories with a density between 9 and 16 m^2/ha of trees 24 cm DBH or larger may need a light improvement cutting to increase tree quality of residual stems and permit more light to reach hemlock seedlings/saplings in the understory. No improvement cutting is recommended if there is little potential for future development of the overstory (i.e., stems will not improve in log quality and maintain growth and tree vigor over time).

A light improvement cut should focus on removing trees:

- with dieback in the upper crown and/or dead tops
- with V-forks in the lower bole
- that are excessively crooked
- with stem wounds that are not healing, particularly those with ground contact
- of undesirable species.

See **Section 5.3** for more detail on tree health, vigor, and risk. By removing inferior trees, overall stand quality increases and the best trees remain to increase in diameter and value.

Overstories with a density greater than 16 m^2/ha of trees 24 cm DBH or larger should have an improvement cut applied to reduce basal area to 16 m^2/ha. However in stands with a dense hemlock overstory (i.e., > 24 m^2/ha of trees 24 cm in DBH), improvement cuts should not reduce the basal area by more than one-third.

6. and 7. Polewood stands

Management options in polewood hemlock stands are determined by whether there is an overstory and whether the overstory has any potential for future development.

Polewood stands without an overstory

In stands with no overstory the recommended prescription is to apply a crop-tree release and thinning. To apply a crop-tree release, the best 100 crop trees per acre (247 per ha) should be chosen. Crop trees should have the following characteristics:

- A healthy, wide and deep crown; trees with live crown ratios greater than 50 % respond quickly, those with less than 30 % respond much more slowly (Anderson 1994).
- No open stem wounds, V-forks, or old dead tops with new leaders; also avoid trees with broken/dead limbs, seams, and injuries in the butt log, because these deformities are associated with rot, decay, and shake (Perkey *et al*. 1993).
- Suppressed understory trees are good crop tree candidates with hemlock. The older hemlocks are when released, the more they seem to respond. Suppressed trees seem to have fewer problems with butt rot and shake (Perkey *et al*. 1993).

These crop trees are then subsequently released on a maximum of two sides of the crown. Trees whose crowns touch (or are very near to) the crop-tree crown are removed on two sides of the crop tree. Excessive release (i.e., four sides of the crown) can result in reduced growth or mortality and contributes to windthrow (Godman and Lancaster 1990).

Polewood stands with overstory

In polewood stands with an overstory with potential for future development, the recommended management prescription is to apply crop-tree release to the polewood and light improvement cutting to the overstory. Overstories with no potential for future development should be removed. Crop-tree release is then applied to the remaining polewood stand.

7. and 8. Sawlog stands

Management options for sawlog stands are determined by the quality of the stand, and whether or not there is any hemlock regeneration.

Overstory with no potential for further development

Sawlog stands with little potential for further development are at the rotation age and should be regenerated. If there is no satisfactory regeneration in the stand, the stand should be regenerated using a three-cut uniform shelterwood system. Three-cut shelterwoods are ideal because they compensate for slow hemlock seedling development by shading out other species.

The first cut is the preparatory cut and it is made in a good seed year. It reduces the canopy closure to about 80 %. Removal of hardwoods is favored and logging is carried out in the summer months to encourage scarification (i.e., exposure of mineral soil). Additional scarification may be required to provide adequate seedbed conditions (Anderson 1994*a*).

After the preparatory cut seedlings will establish themselves. At this point, the success of hemlock establishment should be evaluated carefully. Excessive hardwood competition may have to be controlled (Perkey *et al.*1993), and hemlocks may have to be artificially seeded or planted if the seed crop has failed. If planting is required, seedlings should be obtained from a seed zone as close as possible to that of the planting site (**Figure 4.1.4**).

The second cut occurs once the regeneration is well established, generally 10 years after the preparatory cut. Regeneration should be at least 30 cm in height and marking should leave a residual canopy closure of 50 percent. Logging should be carried out in the winter to protect the regeneration (Anderson 1994*a*).

The third or removal cut is done when the regeneration is at least 1.5 meters tall and preferably 3 meters tall. This will occur at least 10 years after the second cut. This height is required to ensure successful release of the regeneration (Anderson 1994*a*).

Common associates in hemlock stands such as white pine, white cedar, sugar maple, and yellow birch will also regenerate successfully under the uniform shelterwood system (**Sections 6.5, 6.6, and 6.1,** respectively). The landowner should determine the desired proportion of each species in the regenerated stand. The amount of each species that regenerates can be controlled in part by the number of each species left as seed trees.

If there is adequate regeneration present under an overstory with no potential for future development, management focuses on reducing the overstory density and allowing the regeneration to grow. If overstory density is greater than 16 m^2/ha of 24+ cm DBH trees, density should be reduced to 16 m^2/ha through improvement cutting. If density is less than 16 m^2/ha, do nothing and re-assess the situation once the regeneration has reached polewood size.

Overstory has potential for future development

The selection system is applied to stands with an overstory with the potential for future development. Both the single-tree and group selection systems can be used to regenerate hemlock and to convert even-aged stands to uneven-aged ones. The single-tree selection system will also successfully regenerate sugar maple; group selection will successfully regenerate yellow birch, white pine and white cedar.

The selection system should be applied to even-aged stands once the rotation age is reached thereby converting stands to uneven-aged management over time. It is difficult to define a rotation age for hemlock as even small trees could have been suppressed for years. Rotation age for hemlock stands might best be considered to be the time when log quality begins to deteriorate on a site. In the northeastern United States, rotation age in hemlock is commonly reached when the average hemlock diameter is 40 to 45 cm (Perkey *et al.* 1993). Landowners in southern Ontario who are interested in managing stands for old-growth characteristics should consider leaving hemlock stems to grow much larger. The selection system can be used to remove material that has begun to decline, promoting growth of healthy canopy trees and regeneration.

To implement the single-tree selection system on a site, use the following guidelines from Anderson (1994*a*):

- The first cut should leave a residual basal area of 23 m^2/ha, but not reduce the stand's basal area by more than one-third.
- Harvesting should be done in snow-free periods to encourage scarification.
- A salvage cut may be needed five years after the first cut to salvage any mortality.
- A 10-year cutting cycle should be used leaving a residual stocking level of 18 m^2/ha in subsequent cuts.

Little hemlock regeneration may become established between harvests because of the lack of scarification (Kittredge and Ashton 1990).

Group selection could also be used to regenerate hemlock using the following guidelines from Anderson (1994*a*). See **Section 6.1** for more information on group selection.

- Maximum size of openings should be one-half tree height. Small openings limit light and competition from intolerant species, and limit drying of seedbeds.
- Openings must be scarified to expose suitable seedbeds (Godman and Lancaster 1990).

The selection system is more suited to stands being managed for wildlife habitat as well as timber. With the selection system, two to three hemlock can be left in clumps to provide cover for white-tailed deer, and to provide a more permanent conifer cover for a range of wildlife. The selection system also allows a forest manager to leave old hemlock supercanopy trees, some of which may range in age from 200- to 500-years-old. Old-growth features are also best preserved under the selection system (see the subsection on managing hemlock for old-growth features in the following).

Stocking guides for managing even-aged hemlock stands

A stocking guide is available to assist in managing even-aged hemlock stands (**Appendix E**). The ideal stocking level recommended for a stand depends on the proportion of hemlock in the stand. Mixed stands with little hemlock are maintained at lower stocking levels than stands with greater than 50 % hemlock. A stocking guide shows forest managers how a stand is occupying the area available to it, and how much the stand can be thinned without wasting growing space. For example, if the average basal area in a stand is 25 m^2/ha in a stand with 75 % hemlock, the average stocking level is around 850 trees/ha. If a stand had 1000 trees/ha, 150 trees/ha could be removed evenly throughout the stand to maximize growing space available to each residual tree. In general, average stand diameter should be 20 cm at this stage of stand growth.

Managing uneven-aged stands of hemlock

Uneven-aged stands can either be managed as uneven-aged stands or converted to even-aged stands. Typical situations where conversion to even-aged management may be appropriate include:

- quality of canopy hemlock trees is declining through dieback, insects, physical damage, or suppression
- there has been a significant increase in the proportion of undesirable species in the stand and/or decline of hemlock proportion in the stand
- there is significant browsing pressure. The best solution to limit browse damage may be to promote abundant regeneration over wide areas (Schaffer 1996). Even-aged systems produce abundant regeneration over large areas; uneven-aged systems produce small amounts of browse, and it is sometimes concentrated in smaller areas.

To manage an uneven-aged stand, use the single-tree and group selection guidelines provided previously in the 'Overstory has potential for future development' subsection.

To convert an uneven-aged stand to even-aged management, use the decision key provided in the previous section. When deciding on hemlock size (i.e., sapling, polewood, or sawlog), choose the dominant size class in the stand. For example if there are one or two scattered hemlock canopy trees and abundant polewoods, use the polewood section of the decision key.

Managing hemlock stands for old-growth features

Hemlock is a very long-lived tree and as such can be an important component of old-growth ecosystems. The record age for hemlock is 988 years (Godman and Lancaster 1990) and many stands of mature hemlock are quite old (e.g., 200 to 250 years). Hemlock is the longest living forest tree in Ontario (Stabb 1996), and only white cedar survives as long on the Niagara Escarpment. Two options exist for older stands: leave the stand alone or manage it for old-growth features by harvesting some wood products while preserving valuable features for wildlife and conservation. The former option is probably more appropriate for landowners who are less interested in timber production and more interested in wildlife, forest recreation, and appreciation of the aesthetics of older woodlands.

Desirable old-growth features in any stand include:

- large trees or old trees
- trees with few branches to canopy (clear bole)
- many layers in canopy
- large canopy gaps
- uprooted trees
- large dead or broken trees
- logs and woody debris
- tree species diversity
- hummocks from pits and mounds of fallen trees and root tip-ups
- undisturbed soil and woody debris with associated greater water retention

Many of these features can be restored to managed woodlots, enhancing wildlife habitat and biodiversity. The group selection system can be used to create canopy openings. A range of canopy opening sizes will encourage the regeneration of several different species. For example, gaps 6 to 10 m in diameter will promote regeneration of shade-tolerant species such as sugar maple or hemlock. Gaps 10 to 50 m in diameter will favor mid-tolerant species such as the oaks and white pine, while openings larger than 50 m in diameter will favor intolerant species such as aspen, tulip tree, and white birch (**Table 6.1.10**). However, large openings are not recommended in small or fragmented stands. Canopy gaps should be spaced 50 m apart and at least 30 m from the edge of the stand to avoid creating additional edge habitat and minimize forest fragmentation and invasion by undesirable species, especially exotics.

Pit and mound topography can be restored by allowing declining and dead trees to fall naturally. Once on the ground, these trees will provide habitat for a variety of species. To restore old-growth features, 10 fallen logs, preferably ones that are at least 2 m long and 60 cm in diameter, should be left in every hectare of forest. By allowing twigs and branches to decompose naturally on the forest floor, organic material can be enhanced. Ground vegetation can be better protected and encouraged by logging in winter when snow provides some protective cover.

Hemlock logs can persist for extended periods of time on the forest floor and it can take up to 200 years for them to lose their structural integrity and become partially incorporated into the soil. In old-growth hemlock forest in Wisconsin, stands greater than 350-years-old accumulated over 65 m^3/ha of logs, distributed across all decay classes (Tyrrell and Crow 1994).

Studies in the Lake States (Goodburn and Lorimer 1998) found that the amounts of downed woody debris in managed stands were much lower than in old-growth stands; volume of fallen wood greater than 10 cm in diameter was significantly lower in a selection stand (60 m^3/ha) and even-aged stands (25 m^3/ha) than in old-growth stands (99 m^3/ha). The large amount of downed woody debris often found in old-growth stands may not develop in managed forests, but landowners can try to conserve as much of this material as possible.

Cavity trees and snags can be preserved to promote old-growth features in a woodlot. Six living cavity trees and a minimum of four small snags less than 50 cm DBH and one large snag greater than 50 cm DBH should be left per hectare (OMNR 1998*b*). Snags can be created through girdling unmerchantable trees during thinning or regenerating operations. Studies in the Lake States discovered that the density of snags greater than 30 cm DBH in northern hardwood selection stands averaged 12 per hectare, approximately double that found in even-aged northern hardwoods, but only 54 % of the level in old-growth northern hardwoods. Highest densities of snags larger than 30 cm in diameter occurred in old-growth hemlock-hardwood stands, averaging more than 40 snags per hectare. Cavity tree density in selection stands averaged 11 trees per hectare, 65 % of the mean number in old-growth stands (Goodburn and Lorimer 1998). In many forests managed for old-growth features, these high snag and cavities numbers may not be achievable, but landowners should aim to retain as many as possible.

Mast trees can be promoted to provide food for wildlife. Hard mast species such as oak, beech, butternut, and hickory are preferred, but soft mast species such as cherries and mountain ash also supply important forage. Seven mast trees should be promoted per hectare (Naylor 1999).

Supercanopy trees are trees such as white or red pine that rise above the rest of the canopy and provide landmarks for birds and nesting, roosting, or escape cover habitat. At least one cluster of pines, hemlocks, or spruces should be left in every three to four hectares with three to four trees per cluster. Studies in central Ontario have found that stands disturbed by fire usually have up to 50 pine or hemlock canopy trees per hectare that survive to become supercanopy trees in new stands. The average density of supercanopy trees was found to be 16 pine or hemlock trees per hectare in Temagami (OMNR 1998*b*). Supercanopy trees near wetlands and along shorelines of water bodies provide habitat for eagles and ospreys. It is recommended that three supercanopy trees be left within 400 m of bald eagle and osprey nests, and that one supercanopy tree be left per 650 m of shoreline in nesting areas (OMNR 1998*b*).

Section 7

Predicting Effects of Silvicultural Treatments

by Tim Williams

INTRODUCTION

Managing forest ecosystems for a variety of objectives requires a sound understanding of the spatial and temporal character of forest stands and the ability to assess stand responses to disturbance. It also requires some knowledge of how to predict short- and long-term ecosystem relationships and current and future values, as well as how to assess and maintain biological diversity. Focused research programs provide much of this information.

The primary goal of forest growth and yield research is to predict forest stand dynamics and the growth of stemwood biomass. In Ontario, growth and yield research is conducted using Permanent Sample Plots (PSPs). A network of PSPs, which are periodically re-measured, provides data about forest dynamics. Predictive models, ranging in complexity and scope, can then be constructed using data from these PSPs. A height curve predicting tree height based on observed diameter is an example of a simple model. This model can take the form of a simple graph depicted on a sheet of paper. Sophisticated computer growth models that predict the dynamics of entire forest stands are far more complex.

Discussion of forest growth and yield involves the use of specific terminology. The Glossary of Technical Terms provides definitions of commonly used growth and yield terms.

7.1 WHY TRY TO PREDICT EFFECTS OF SILVICULTURAL TREATMENTS?

T. Williams

In **Section 4.1**, factors contributing to the variability of forest productivity on different sites were briefly discussed. The interacting effects of latitude, elevation, climate, landform, bedrock geology, and soil texture and moisture determine the potential of a given site to grow trees of various species, sizes, and quality.

Due to the variable nature of forest productivity, silvicultural treatments might have quite different effects on one stand than they would have if the same treatments were applied to a similar stand occupying a different type of site. Similarly, silvicultural treatments applied to a different type of stand on the same site type could produce different results. Therefore, it is appropriate to customize silvicultural treatments to specific stands and sites. In order to do so properly, the forest manager must be able to predict the effects of a range of treatments in order to evaluate each one of them within the context of management objectives and to select the treatment that best applies to the existing scenario.

- For example, consider two hardwood stands – one on a highly productive site and another on a less productive site. Both stands are well suited to partial harvest using the selection system. The stand on the highly productive site might grow enough volume after the first cut to allow another cut to occur 17 years later. The less productive stand might require 22 years before a second cut is appropriate. In this example, the forest manager must know the rate at which these stands grow tree volume over time.

- Or, consider two different stands dominated by the same species. One stand might be located on an ideal site for that species; the other might be "off-site", where a different species could be more productive.

In order to determine management objectives for each stand, site index models can be of assistance. These models indicate tree species' relative productivity on various site types, and can help forest managers decide which silvicultural methods to apply to a stand.

7.2 WHAT INFORMATION AND TOOLS ARE USED TO PREDICT EFFECTS OF SILVICULTURE TREATMENTS?

K. Elliott

The main factors that determine the growth and yield response of stands and individual trees can be grouped into three major divisions: site quality, individual tree characteristics, and stand level characteristics.

Site quality

As discussed in **Section 4.1**, many variables contribute to the ability of a site to support tree growth. Forest managers use two important measures of site productivity: site index and site class.

Site index

One of the most commonly used measures of site productivity for *even-aged* stands is site index (SI). Site index is a measure of tree height at a standard age (called the *index age*) and varies according to species. Site index is often represented by curves that depict the relationship between height and age of trees. Trees measured for site index must be those that have always been free from shading by neighboring trees. These trees reflect the potential (height) growth rate of an individual tree. Height growth is relatively unrelated to stand density, yet closely correlated to volume. Thus, two stands with the same initial density but different SI values will not produce equal volumes. The higher yield will occur in the stand with the greater SI value (Carmean *et al.* 1989). SI values in Ontario are usually described on a base age of 50 years. Measurements of stand age and stand top height are all that is required to determine SI. A stand with a height growth pattern intersecting 20 m at 50 years has a SI 20; another stand intersecting 22 m at 50 years has a SI 22.

Site index is often required as an input value for many of the growth models that have been developed in the United States (e.g., Fiber 3.0 (Solomon *et al.* 1995**)**, SILVAH (Marquis and Ernst 1992) and NE-TWIGS (Belcher 1992)). These estimates of site productivity are often considered to be the "growth engines" of many growth models.

Site index curves for 12 species covered in this guide are included with the individual species fact sheets in **Appendix E**. **Appendix D** contains a guide to tree species suitability for site regions 6E and 7E (Taylor and Jones 1986). This appendix presents site index and site class information for several tree species, based on field recognizable soil properties. These tables are useful when resource managers are setting management objectives for a given site, as they provide estimates of which tree species are likely to be most productive. The tables may also explain why poor productivity is observed in some stands (i.e., species are not suited to site conditions).

Site class

Site class is a group of species-specific site indices. It is a more generalized form of site quality classification than site index. Ontario has a three-class system that is published in Plonski's (1960, 1981) normal yield tables.

Ranges of Site Indexes (SIs) were divided into poor (Site Class 3), good (Site Class 2), and better (Site Class 1) SI groupings. Plonski developed these classes empirically by hand-fitting a curve through individual height-age measurements for multiple plots per species. Using this first curve as a guide curve, curves of the same shape were drawn one standard deviation above and below to create the boundaries of the site classes. Plonski's curves are of similar shape for differing site classes or ranges of SIs. Today it is generally understood that such curves are less representative of stand height-age-site development patterns than curves with variable shape. Nevertheless, Plonski's Site Class curves still provide the basis for site productivity classification in Ontario.

Table 7.2.1: Input requirements for various types of volume tables.

TYPE OF VOLUME TABLES	REQUIRED INPUTS							
	Species	DBH	Total Height	Merchantable Height	Stump Height	Top Diameter	Age	Cull %
Local Volume Table	✕	✕						
Form-class Volume Table	✕	✕		✕				
Standard Volume Table (GTV)	✕	✕	✕					
Standard Volume Table (GMV)	✕	✕	✕		✕	✕		
Standard Volume Table (NMV)	✕	✕	✕		✕	✕	✕	✕

[1] Smalian's formula: V = L *(a1+a2)/2 where V = volume (m^3), L = log length (m), a1 = cross-sectional area at base of log (m^2), a2 = cross-sectional area at top of log (m^2).

Individual tree characteristics

Volume tables

Volume tables or equations provide estimates of individual tree volumes from previously established relationships among easily measured tree characteristics such as diameter, height, and tree form. *Form-class,* s*tandard*, and *local* volume tables are used in Ontario. A summary of the inputs required for each type of volume table is presented in **Table 7.2.1.**

Form-class volume tables have been used in Ontario for over 60 years (Anon. 1930, 1948). They were used to estimate total and merchantable yields of individual trees, or sections of trees, and were usually based on Smalian's formula[1]. In Ontario, Form-Class 65, 70, 75, and 79 volume tables have been used for a variety of species (Berry 1981; Staley 1991). The Form-Class 79 volume table has been tested throughout the tolerant hardwood forests of Ontario and it is the preferred volume table for estimating the volume of standing timber (**Appendix E**). Total fuelwood volume in the remaining tops is estimated by multiplying the form-class volume estimate by 0.8 (Staley 1991).

The calibration of form-class volume tables for local conditions requires measurements of stem diameter at some specified upper height, usually the top of the first log (e.g., 5.28 m). However, local form-class-diameter relationships were not easily constructed because of the difficulty in measuring upper stem diameter and dealing with variations in tree form. Often tree form was not measured and tables were arbitrarily assigned to each species (Honer *et al.* 1983). This led to the development of standard volume tables that express the volume-diameter-height relationship without the need for tree form.

Standard volume tables for Ontario (Honer 1967; Honer *et al.* 1983) provide an estimate of the total inside-bark volume for individual trees. This method requires DBH and total tree height to estimate volume. These tables are often well documented and provide information on sample size, data range, construction methodology, date of preparation, and measures of accuracy. Standard equations are developed by destructively sampling a large number of trees per species across the range of ecosites that the species occupies. Honer's (1967) sampling was done throughout Canada. Standard volume tables for 12 species covered in this guide are presented with their respective fact sheets in **Appendix E.**

Local volume tables are a modification of standard volume tables based on the species DBH-height relationship within a given area. Incorporation of the local DBH-height relationship eliminates the need to measure tree heights; volume is based solely on DBH. Local volume tables are commonly used during operational assessments of forest inventories. A common problem with the use of local volume tables occurs when resource managers use tables that have not been developed specifically for their site, species, and quality conditions. Therefore, managers should periodically calibrate their local volume tables by validating the diameter height relationship.

Stand level characteristics

Growth and yield characteristics of groups of trees (i.e., forest stands) can be accounted for by using either yield tables or stand and stock tables.

Yield tables for *even-aged* stands are one of the oldest tools for estimating yields. Early yield tables only provided volume estimation, at different ages, for a given forest unit. Modern tables often include stand height, mean diameter, number of stems, stand basal area, and current and mean annual volume increments, in addition to accumulated volume estimates (i.e., yield). Yield tables are used to:

- predict growth and harvestable volume, and
- provide conceptual models of stand development.

Yield table estimates of growth and future harvest volume are good enough to plan both the timing and marketing of the harvest (Philip 1994).

The three most common classes of yield tables are: *normal*, *empirical*, and *variable density*.

Normal yield tables (e.g., Plonski 1960, 1981) provide estimates of expected yields tabulated by stand age and site index (or grouped into site classes) for ideal, fully stocked or "normal" forest stands (Vanclay 1994). They are usually derived by combining temporary sample plot data and stem analysis. The volume of an existing stand may be estimated with a normal yield table by adjusting the published yield values by a percentage of the expressed normality that is usually based on basal area. Normal yield tables provide reliable estimates of potential yields for even-aged stands that are like the stands used to develop the tables, but estimates may be poor in natural stands whose age varies considerably from those used in table construction (Vanclay 1994).

Table 7.2.2 provides yield estimates, for even-aged stands of four hardwood forest cover types in Site Region 6E and two hardwood forest cover types in Site Region 7E. Where data from enough PSPs was available, yield estimates were derived for both unmanaged and managed stands. For comparison purposes, yield estimates for the uneven-aged upland tolerant hardwood forest cover type in Site Regions 5E are presented in **Table 7.2.3.** Continued long-term monitoring of growth rates in PSPs is necessary to produce estimates exclusively for uneven-aged hardwood stands, both for unmanaged stands and those managed by the selection silvicultural system in both Site Regions 6E and 7E.

Empirical yield tables are similar to normal yield tables in their construction and use. The difference is that empirical tables are based on sample plots of average rather than full stocking. According to Husch *et al.* (1972), "the judgment necessary for selecting fully stocked stands is eliminated, simplifying the collection of field data." Yield tables developed in this manner display stand characteristics for the average stand density encountered in the collection of the field data.

Table 7.2.2: Yield estimates for even-aged hardwoods by forest cover type, Site Region, and residual BA class.

		Unmanaged		Managed**		Estimate Basis		
Forest Cover Type and Site Region	Residual BA Class*	BA Increment (m^2/ha/yr)	GMV Increment (m^3/ha/yr)	BA Increment (m^2/ha/yr)	GMV Increment (m^3/ha/yr)	# Obs. (control / managed)	# stands (control / managed)	# years (control / managed)
Early Successional Hardwoods - 6E	35	0.06	4.02	0.34	4.72	6 / 9	1 / 1	4-5 / 5
Lowland Hardwood or Swamp - 6E	30	0.31	5.00			3	1	5
Lowland Hardwood or Swamp - 6E	35	0.13	5.88			8	1	5-8
Upland Oaks - 6E	20	0.37	6.26			2	2	5
Upland Oaks - 6E	25	0.45	5.89			3	1	5
Upland Oaks - 7E	20			0.31	3.53	3	1	5
Upland Oaks - 7E	25	0.47	4.91			6	1	5
Upland Tolerant Hardwood - 6E	20	0.42		0.41	4.41	13 / 2	2 / 5	5-7 / 1-7
Upland Tolerant Hardwood - 6E	25	0.27	3.22	0.47	4.55	58 / 23	10 / 7	4-8 / 5-8
Upland Tolerant Hardwood - 6E	30	0.06	2.93	0.36	5.70	68 / 7	11 / 2	5-7 / 3-5
Upland Tolerant Hardwood - 6E	35	0.15	4.37			31	6	4-6
Upland Tolerant Hardwood - 7E	20			0.71	8.01	3	1	5
Upland Tolerant Hardwood - 7E	30	0.37	6.08			11	1	3-7
Upland Tolerant Hardwood - 7E	40	0.00	0.31	0.59	8.38	3 / 4	1 / 2	2 / 1-7

(based on data collected from trees 10 cm in DBH and greater)

* BA Class represents midpoint:

20	17.5-22.4 m^2/ha
25	22.5-27.4 m^2/ha
30	27.5-32.4 m^2/ha
35	32.5-37.4 m^2/ha
40	37.5-42.4 m^2/ha

Management of some of the stands presented ranges from random tree removal to application of recognized silvicultural practices. Potential higher increments may be realized with proper and careful management. **Failure to implement careful logging practices will result in smaller growth increments.

Table 7.2.3: Yield estimates for uneven-aged upland tolerant hardwoods in Site Region 5E, by residual BA class (from Woods *et al.* 1998).

		Unmanaged		Managed**		Estimate Basis		
Forest Cover Type and Site Region	Residual BA Class*	BA Increment (m^2/ha/yr)	GMV Increment (m^3/ha/yr)	BA Increment (m^2/ha/yr)	GMV Increment (m^3/ha/yr)	# Obs. (control / managed)	# stands (control / managed)	# years (control / managed)
Upland Tolerant Hardwood - 5E	10			0.46		18	1	3-4
Upland Tolerant Hardwood - 5E	15			0.38		18	1	3-4
Upland Tolerant Hardwood - 5E	20			0.49		107	3	3-5
Upland Tolerant Hardwood - 5E	25	0.49		0.32		23 / 107	2 / 3	6-7 / 4-10
Upland Tolerant Hardwood - 5E	30	-0.57				6	1	6

(based on data collected from trees 10 cm in DBH and greater)

* BA Class represents midpoint:

10	7.5-12.4 m^2/ha
15	12.5-17.4 m^2/ha
20	17.5-22.4 m^2/ha
25	22.5-27.4 m^2/ha
30	27.5-32.4 m^2/ha

**Managed and Unmanaged stand estimates are based mainly on controlled research trials. Limited operational trial data is presented.

Variable density yield tables include the additional variable of density that permits data from partially stocked stands to be used in their development. This addition also means that variable density yield tables can be applied to stands regardless of their stocking. Recently published variable density yield tables in the boreal forest (Bell *et al.* 1990) use a combination of stand density, stand age, and SI in their presentation of yield information. Variable density yield tables do not exist for tolerant hardwood stands in Ontario.

Stand and stock tables are quantitative descriptions of individual or groups of forest stands for forest inventory purposes. They are used to estimate the amount of useable wood for a variety of products, including pulpwood, fuelwood, or sawtimber. Stand and stock tables are also used to analyze stand structure in the development of intermediate thinning or final harvest prescriptions. The most common stand parameters measured include frequencies of species by diameter and quality class.

A *stand table* is used to present the number of trees by species for a forest, with data often expressed as basal area by diameter, quality, or height classes. Stand tables can be expressed as a unit area (e.g., hectare) or as total forest or stand area. A stand table is useful for showing the structure of the stand (Husch *et al.* 1972).

Once harvest or thinning prescriptions have been developed, current stand yield by product class can be determined. Future stand growth can also be predicted within each diameter or size class, which provides more accurate assessments of future stand structure. Many growth models (e.g., Raymond and McLean 1984) use this method of stand growth projection.

7.3 GROWTH AND YIELD SAMPLING IN SOUTHERN ONTARIO


K. Elliott

A network of 398 Beckwith PSPs (named for the project leader, Alan Beckwith) was established in southern Ontario during the 1960s to 1980s. These plots are located primarily in hard maple stands and conifer plantations. Re-measurements continue to be carried out by the OMNR, and some plots have data from as many as nine observation periods.

To address data needs not met by the Beckwith PSP network, the current OMNR Growth and Yield program began installing enhanced PSPs from 1991 to 1995. These PSPs expanded the type of data collected to include data on downed woody debris, shrubs and vegetation, wildlife evidence and habitat, soils, and forest regeneration.

Re-measurement and expansion of this plot network is ongoing. A complete set of growth and yield tools derived from research in southern Ontario is unavailable for all species discussed in this silvicultural guide. However, growth and yield models from nearby provinces and states are presented in **Appendix E** for species that lack Ontario models. Research will continue in both the development and standardization of these tools for Ontario.

Section 8

Implementing Silvicultural Prescriptions

INTRODUCTION

This section explains and discusses vegetation management; tree marking; and harvesting as they apply to the forests of southern Ontario. A discussion of the many different considerations that apply to silvicultural prescription setting and implementation in southern Ontario's forests concludes this section.

8.1 VEGETATION MANAGEMENT FOR INDIVIDUAL TREE CONTROL

by Silvia Strobl and Wayne Bell

S. Strobl

Introduction

In forest stands, the control of individual unwanted woody and herbaceous vegetation is an accepted method of releasing the desired, usually higher quality and more valuable, crop trees (Holt 1989). Vegetation management is often used in precommercial thinning operations in young even-aged stands. Either systematic crop tree spacing or crop tree selection is used to identify the future crop trees, and the crown touching method (**Figure 6.2.1**) provides a guideline for identifying the competing trees and shrubs to be controlled.

Where single-tree selection is planned for previously high-graded stands, the first treatment will usually be an improvement cut to remove overly abundant trees, poor formed trees, or unhealthy trees. If there is no market for firewood, such cuts may involve girdling and/or the application of herbicides to low quality, canopy trees.

Where group selection is used to maintain advanced reproduction or encourage regeneration of mid-tolerant species, vegetation management may be required, either before or after group openings are made. In many stands, non-crop competitive species often become more abundant in the sunnier, open conditions of forest gaps. Controlling this competing vegetation provides more favorable growing conditions for the desired mid-tolerant species.

Also vegetation management may be required to control invasive exotic species in southern Ontario forests. **Section 4.2** discusses the problems associated with invasive exotic species; the most problematic invasive exotic species in southern Ontario forests are listed in **Table 5.1.2**. This section recommends control treatments for several invasive exotics commonly encountered in southern Ontario woodlands.

Two methods of controlling unwanted, competing vegetation are appropriate in natural forest stands: brushing or selectively applying herbicide. In both methods, treatments are selectively applied only to the stems of competing trees and shrubs to minimize negative effects on native herbaceous cover (i.e., they encourage the release of established seedlings, saplings, and polewood from unwanted tree and shrub competition).

This subsection discusses manual/motor-manual and herbicide methods for controlling individual unwanted stems, including a description of tools, herbicides, and application techniques. Responses of common competing trees, shrubs, and vines to either cutting or herbicides and control treatments for the most serious invasive exotic species are also presented.

Since most stands in southern Ontario are relatively small and located fairly close to houses and main roads, managers must take several precautions prior to brushing or applying herbicide in a woodlot. These include:

- notifying adjacent landowners that vegetation management techniques will be implemented, and
- posting the property according to the guidelines required under the Ontario Pesticides Act.

Brushing

Brushing is defined as the "removal of undesirable woody and herbaceous vegetation by manual or mechanical means" (Canadian Forest Service 1995). It is used for site preparation or for tending. Mechanical brushing (i.e., use of a tractor-mounted mower) is rarely appropriate in southern Ontario, except for site preparation in stands undergoing species conversions. Manual and motor-manual tools are more commonly used for tending treatments such as crop-tree release from competing vegetation or precommercial thinning.

Before chemical herbicides, manual removal and mechanical options were the most common methods available for the removal of competing vegetation. After the Second World War, chemical herbicides became readily available and were more widely used. Today cutting techniques have regained some of their past popularity due largely to environmental concerns about herbicides (Cox 1994), coupled with their selectivity for individual tree release and suitability for use along sensitive areas of concern. Manual and motor-manual brushing are sometimes the only tools available in some parts of southern Ontario (e.g., within urban areas) where municipal policies have banned the use of herbicides.

> The recommendations in Section 8.1 are those of the authors and should not be construed as either policy or endorsement by the Ontario Ministry of Natural Resources (OMNR). The use of trade names does not constitute official endorsement or approval by the OMNR to the exclusion of any other suitable product or process.

Manual brushing tools

Manual brushing tools (e.g., shears, Sandviks/brush axes, machetes, brush hooks and axes) are often used on sites with rough terrain or low-density brush. They are economical and relatively safe to use, and require little maintenance or training to operate. These tools are only appropriate for cutting woody, brushy vegetation and are not suitable for removing grasses or herbs. Since most of these tools can leave a short, pointed spear-like stump that can be dangerous to wildlife or people walking in the area, they may be inappropriate for use in areas with high recreational use. Furthermore it is a labor-intensive treatment and costs can be prohibitive unless a ready supply of inexpensive labor is available (Obermeyer 1992). However, it may be economically justified for the release of a few hundred oak crop trees per hectare, for instance.

Shears

Shears are available in many sizes and with various cutting head designs. They are ideally suited for manually cutting brush up to 7.5 cm in diameter, around crop trees where crew safety is a concern, power tools are not an option, and zero damage tolerance to crop trees is desired. Their best use is in established plantations where crop trees are difficult to see and the number of stems to be removed is low. Here they can be used to selectively remove brush from around crop trees that could be scarred or damaged by power tools. Shears are not widely used in forestry and most will not stand up to forestry use (Boateng and Ackerman 1990).

Sandviks/brush axes

Sandviks (also known as the Swedish Brush Axe) are made of a steel D-shaped head with a replaceable blade attached to a wooden axe type handle. The Sandvik is most useful in low and medium brush situations where power tools are not an option. Sandviks can be used in all weather and most terrain conditions to selectively remove brush from around crop trees. Their use is limited to stems of less than 6 to 7 cm in diameter (Boateng and Ackerman 1990).

Machetes

Machetes are comprised of a 46 to 61 cm blade shaped like a short broad curved sword attached to a handle grip. They are widely available, although it is sometimes difficult to find one with a strong enough blade for forestry purposes (Boateng and Ackerman 1990). The machete is useful in light to moderate brush situations with stem diameters less than 5 cm, where power tools are not an option. The wider cutting surface of the machete allows it to clear more brush in one sweep than the Sandvik (Boateng and Ackerman 1990).

Brush hooks

The brush hook consists of a treated steel 23 to 27 cm hooked blade attached to a wooden handle similar to an axe handle. It is designed for the same conditions as the machete (Boateng and Ackerman 1990).

Axes/hatchets

Axes come in many shapes and sizes. They can be used to cut brush and saplings of virtually any size, but their productivity is low (Boateng and Ackerman 1990). Axes tend to bounce off small springy stems, and are not recommended, except for girdling or frilling (see following discussion of Manual/motor-manual brushing techniques) of larger diameter stems, due to safety concerns.

Weed Wrench™

The Weed Wrench is an all-metal tool that is very effective at pulling small to large trees out of the ground, even out of dry, hard soils. It has a set of jaws which clamp strongly onto the stem, and let you lever the plant out of the ground. Wrenching invasive exotic plants out of the ground can disturb the soil, however, and encourage new weeds to sprout. Sites should be monitored after treatment. Four different sized models are available: heavy (handles up to 6.4 cm stems), medium (5 cm), light (4 cm), and mini (2.5 cm). The Weed Wrench should not be used to pull plants with long, deep-rooted tap roots as this will snap the root below-ground and if the plant can resprout from the roots, will not provide effective control.

Prices, shipping costs and other information is available from the manufacturer, New Tribe, at (541/476-9492) or http://www.canonbal.org/weed.html.

Root talon

The root talon is an inexpensive, lightweight alternative to the Weed Wrench. It is a tool shaped like a pick-axe, but with a specialized fork and gripping flange that will let you grab onto plant stems and pull them out of the ground. It does not have the same pulling strength as the weed wrench, but it is lighter to carry. It is very effective against shallow-rooted plants like garlic mustard, or other herbs that have sturdy but flexible stems. It is also effective for pulling sapling trees and shrubs (less than 3 cm in diameter), for example of the shallow-rooted buckthorn. However, soil disturbance may stimulate seeds in the soils seed bank to germinate. It can be obtained from the manufacturer, Lampe Design at (612/699-4963) or http://www.buckthorn.com/index.htm.

Motor-manual brushing tools

Motor-manual tools (e.g., brush saws and chain saws) can be used on fairly rough terrain and for selective release operations. These tools are more productive than manual brushing tools and are useful for cutting stems of much larger diameters. The stumps left after brushing with motor-manual tools tend to be flatter and duller than those left after using manual brushing tools, resulting in less hazard for people and wildlife walking through the cut area. However, they are more expensive to operate. Their indiscriminate use during release operations can damage young crop tree seedlings. Also machine down time can reduce productivity.

Since these tools can be very dangerous, an intensive worker-training program and protective clothing are required (Holmsen 1989). A proper maintenance schedule must be followed in order to keep the saws in good running order.

Brush saws

Brush saws, also known as clearing saws, have been described as resembling large weedeaters (Boateng and Ackerman 1990). There are numerous makes and models, but each one consists of a gasoline engine attached to a 1.7 m shaft that powers a cutting blade. An adjustable harness holds the unit to the worker's right side and the engine is positioned behind the operator. This design distributes the weight of the saw evenly on the operator's shoulders. Brush saws are safer and easier to operate than chain saws, however they are not as productive in rough terrain (Boateng and Ackerman 1990) or larger-diameter stands (De Franceschi and Bell 1990). They can cut stems up to 15 cm in diameter, and stump height can be as low as 1 cm above ground level (Dominy 1987). They are best used where the crop trees are clearly visible, slash conditions are low, and the terrain is flat to gently sloping (Boateng and Ackerman 1990).

Chainsaws

Several makes and models of chainsaws are available for forestry brushing operations. Modern chainsaws are lighter and more compact than their earlier counterparts. They are versatile silvicultural tools that can be used for brushing as well as simultaneous juvenile spacing. Chainsaws can be used to cut through stems and slash of virtually any size. They are more useful than brush saws in extremely rough terrain, tend to be a more productive tool for brushing, and require less training. However, they are more difficult and dangerous for the operator to use than brush saws and tend to leave higher, more angled stumps. Chainsaws are best suited to rough terrain and heavy slash conditions, where brush saws are of limited use, and where most stems are greater than 7.5 cm in diameter (Boateng and Ackerman 1990). Workers may experience discomfort from chainsaw exhaust, especially if working in deep snow, thick forest stands, or calm weather (Nilsson *et al.* 1987).

Manual/Motor-manual brushing techniques

Girdling

Girdling is sometimes used to remove unwanted, larger diameter trees. An axe or chainsaw is used to cut through the bark and into the wood around the entire stem of the tree. Usually this is done with a chain saw, and two rings, 5 to 10 cm apart, are cut around the circumference of the tree. A double chainsaw girdle is more effective in reducing the likelihood of the cambium growing over a single narrow cut (Holt 1989).

Frilling

Another technique for controlling unwanted larger diameter trees is frilling, a variation of girdling. With an axe, hatchet or chainsaw, a series of downward cuts is made around the tree, but the bark and wood are left as a flap into which a herbicide is added to improve control treatment effectiveness. The addition of herbicides helps prevent the tree from growing over the frill (Holt 1989). Appropriate herbicides are discussed in the subsection Selectively applying herbicides.

Girdling is not recommended in forest stands with high recreational public use due to the potential future safety hazard from falling trees. However, girdling can be an effective method to accelerate the creation of snags in young forest stands or stands where few snags are currently present.

Vegetative response to cutting

Response of woody plant species

The effectiveness of brushing as a vegetation management tool is significantly affected by season. Cutting of root suckering species such as aspen after leaf flush has been found to reduce suckering as compared to cutting in the spring prior to leaf flush or any time during the dormant season (Stoeckeler 1947, Weber 1991; Bell *et al.* 1999). Similarly, cutting of basal sprouting species such as red maple, white ash, and black cherry, at the very beginning of the growing season or at the end of the growing season resulted in the highest sprout production (Kays and Canham 1991). **Table 8.1.1** summarizes responses of woody plant species to cutting.

Table 8.1.1: Responses of woody plant species to cutting and three herbicides (adapted from Harvey *et al.* 1998 and McLaughlan *et al.* 1996).

Family	Species	Response to cutting	Response to herbicide		
			Glyphosate	2,4-D	Triclopyr
Maple	red maple	• may not significantly reduce stem density for more than 1 year due to sprouting	I	?	S
	sugar maple	• stumps, especially smaller stems, will sprout profusely	?	?	S
	mountain maple	• will grow in clumps after cutting • temporary increase in stem density • stems should be cut at 15 cm from the ground	S-I	I-R	S
	speckled alder	• sprouts vigorously and can regrow to 40 to 70% of pretreatment height in one growing season • sprouting is more vigorous if cut during the growing season	S-I	S-I	S
	paper birch	• sprouts from root collar or stump • will increase stump sprouting if stems are cut during the growing season • prolific sprouting will occur when young vigorous trees have been cut in the spring to stump heights of 15 to 30 cm • stems should be cut at ground level	S-I	S	S
	yellow birch	• limited sprouting	?	?	?
	beaked hazel	• stimulates sprout and suckering production • less sprouting occurs if cut late in the growing season as compared with dormant or early growing season	S-I	S	S-I
Buckthorn	common and glossy buckthorn	• stimulates sprout and suckering production • less sprouting occurs if cut after flowering but before substantial fruiting as compared with cutting in the dormant or end of growing season • stems should be cut at ground level (Strobl 1999)	S	?	S
Honeysuckle	bush honeysuckle	• sprouts less vigorously in summer-treated than in fall-treated plots	?	?	?
	high bush cranberry	• sprouting will occur, but recovery may be slow	?	?	?
Dogwood	red osier dogwood	• especially prone to root suckering when cut during the dormant season • early to mid-summer produces shorter and narrower sprout clumps than winter cutting	I-R	S-I	S
Gooseberry	currants and gooseberry	• sprout from root collar	I	I	S
Grape	wild grape	• prolific stump sprouters	?	S	?

Table 8.1.1: *continued*

Family	Species	Response to cutting	Response to herbicide		
			Glyphosate	2,4-D	Triclopyr
Rose	pin cherry	• sprouts following cutting • stem density increases • stems should be cut at 15 cm from the ground	S	S	S
	wild red raspberry	• regenerates rapidly from suckers, stools, and root crowns • repeated heavy cutting will deplete stored food reserves and eventually reduce the number and vigor of canes produced • reducing density of canes increases vigor of remaining ones	S	S	S
	prickly wild rose	• severing aerial stems increases sprout production • will rapidly re-establish from rhizome sprouts; less occurs if treatments applied in June - July when reserves are low	S-I	R	S
	serviceberry	• sprouts following cutting • increases biomass	S	S-R	S
Rue	prickly-ash	• will sprout from underground rhizomes (Louter *et al.* 1993)	S	R	?
Willow	trembling aspen	• will sprout rapidly from stumps or sucker from roots • after leaf flush is more effective in reducing suckers than at other times of the year • sucker production is proportional to the degree of cutting	S	S-I	S
	balsam poplar	• causes sprouting from the stumps or suckering from the roots especially during the winter. • during the snow-free period produces sprouts from callus tissue and dormant buds located in the stump	S-I	S-R	S
	cottonwood	• sprouts may grow 1.5 to 3 m in height in one growing season • number of stems increases by 25 times following number of stems	S-I	S-R	S
	willow	• sprouts 2 to 3 m in height in one growing season; one stem can produce up to 60 sprouts • 3 to 5 times increase in number of stems • best controlled in late summer • most vigorous sprouting if cut during the dormant season	I-R	S	S

S = susceptible; I= intermediate; R = resistant; ? = no information
Note: The above ratings are a generalization of vegetation response to herbicide application under many different conditions. Plant condition and age, season of application, application rate, soil type and weather conditions are among the factors that will cause results to vary.

Sprout growth can be minimized by timing mechanical damage to occur when carbohydrate reserves are at a low point, thereby reducing sprout growth (Hobbs and Crawford 1988). However, the optimum time period for cutting that will result in the lowest resprouting rates will vary from species to species and is related to phenology (i.e., the relationships between seasonal climatic changes and periodic biological phenomena such as flowering and fruiting) (Hobbs and Crawford 1988). Species with determinant shoot growth pattern had the shortest time period during which the cutting treatment was effective (white ash) while the species exhibiting the most indeterminant shoot growth pattern had the longest effective treatment period (Kays and Canham 1991). Similar results were found for dogwood and red alder (Buell 1940, Harrington 1984). Unfortunately, although the autecology for most species suggests that cutting treatments during the growing season would be most effective, mechanical brushing treatments are often implemented in late fall after leaf drop because crop trees are more visible (Conway-Brown 1984).

Box 8.1.1: Explanation of the difference between determinate and indeterminate growth.

Determinate and indeterminate growth refer to different fundamental types of shoot growth.

Determinate growth is also known as 'fixed' shoot growth, and refers to the shoot growth pattern where growth occurs through elongation of pre-formed stem parts, or 'stem units' after a rest period. In determinate tree species, shoot formation involves differentiation in the bud during the first year (*n*) and extension of the pre-formed parts into a shoot during the second year ($n + 1$). Examples of tree species with determinate growth include white and red pine, spruces, fir, white ash, and beech.

Indeterminate growth is also known as ‘free’ shoot growth, and involves elongation of a shoot by simultaneous initiation and elongation of new stem units. Examples of tree species with indeterminate growth include poplar, some maples, and birch.

One of the primary differences between the two types is how growing season conditions affect shoot growth. In fixed growth species, the growing season during bud formation largely determines the potential size of shoot and number of leaves formed the following year. For example, drought during year *n* can reduce the number of needles and shoot length of red pine in year $n + 1$, even if the growing season is favorable for vigorous growth. Indeterminate species will exhibit continuous shoot growth as long as the environment is suitable.

A third, intermediary type of growth is referred to as **'recurrent shoot growth'**. A series of determinate shoots is formed in a given growing season, when climate and growth conditions are favorable. Determinate growth occurs, a terminal bud is formed, and the terminal bud flushes in the same growing season it was formed. An example is red oak, but this occurs primarily in stump sprouts, and nursery grown seedlings (Kozlowski and Pallardy 1997).

The type of cut has also been found to affect the vigor of resprouting. The height of the cut affected the vigor of aspen root suckering; higher cuts over 50 cm were found to reduce aspen sprouting (Bell *et al.* 1999). Alternatively, species that sprout from the root collar, such as red alder, mountain maple, paper birch, and pin cherry should be cut at 10 cm or less (Harrington 1984; Hart and Comeau 1992; Jobidon 1997). The smoothness of the cut also affects regeneration of competing vegetation (Ehrentraut and Branter 1990; Bell *et al.* 1997). The shattered ragged cut of the Silvana Selective, a mechanical brushing tool used in plantations, produced fewer and less vigorous sprouts than the clean cut of a brush saw (Bell *et al.* 1997).

Response of wild grape vines

In southern Ontario, especially in the southwestern region, wild grape vines can damage trees thereby reducing their growth and quality and value as wildlife trees. However, since this vegetation also produces valuable food and cover for a variety of wildlife, managers should carefully evaluate the threat posed by vines before any control is implemented.

Most vines require sunlight to grow well. They sprout prolifically from stumps and they root easily. Periodically they produce large quantities of seed that remains viable in the soil for at least 15 years (Smith 1989). They are usually a more serious problem in stands that have previously been heavily logged.

Recommendations to control growth

Vines growing in sapling, polewood, and immature sawlog stands under even-aged management can be controlled by cutting them close to the ground using blades, hatchets, and chainsaws. Although the cut vine stumps will sprout, shading will kill these sprouts within 3 to 4 years (Smith 1989). Grape vines should not be cut in sapling stands until the crown canopy provides shade, normally about 8 to 10 years after overstory removal (e.g., shelterwood management). If a precommercial crop tree release or thinning is planned and grape vines need control, treat the vines first and then wait at least 5 years before doing the release or thinning to avoid having the overstory removal and resulting change in light conditions stimulate vine growth (Smith 1989).

Herbicide control should only be used when mature stands are ready to harvest. If some even-aged practice is scheduled within the next 4 years for an area with a serious problem, the vines should be sprayed with a herbicide-oil mixture at their base, if they are found on the ground, and on their stems if they are attached to the tree. Vines can be basal-sprayed with this mixture throughout most of the year. Grape seedlings will still germinate in the stand after harvest and will have to be controlled once the stand reaches sapling size (Smith 1989).

If vines are a serious problem, no herbicide control is necessary in a mature stand that will not be harvested during the next 5 years using an even-aged cutting practice, or where no large (e.g., twice tree canopy height in diameter) group selection openings are planned within the next 5 years. The vines can be cut just above the ground; the dense canopy shade will cause the stump sprouts to die within 3 to 4 years (Smith 1989). After such pretreatment of potential vine competition, the overstorey harvest activity can proceed.

In mature stands under uneven-aged management, vines can usually be controlled by cutting those growing in tree crowns before, during, or after harvest. Resprouting vines will die within a few years because single-tree selection harvesting does not provide enough light to stimulate prolific vine growth.

The cost of cutting vines depends on the size and number of vines per hectare. In mature stands, it takes one person about 5 hours to cut 250 grape vines per hectare and about 3 hours to cut 250 vines per hectare in sapling stands. Basal spraying 250 vines per hectare in mature stands takes a person about a 2.5 hours and approximately 4 L of herbicide-oil mixture. Herbicides are not necessary for immature stands unless clearcutting is planned (Smith 1989).

Table 8.1.2: Recommended control treatments for wild grape vines (adapted from Smith 1989).

Type of management	Predominant age of stand	Recommended treatment
Even-aged management (including within a planned future group selection canopy opening)	Seedlings	Cut close to ground using blades, loppers, hatchets, and/or chain-saws
	Saplings	Cut as described above but only when crown canopy provides sufficient shade, normally 8-10 years after cutting
	Polewoods and/or immature sawlogs (during crop-tree thinning or release treatments)	Cut vines first as described above, then wait 5 years until crop-tree thinning or release
	Mature stands that will not be harvested within the next 5 years	Cut vines as above, just above the ground
	Mature stands to undergo harvesting within the next 5 years	Apply herbicide to base of vines growing on the ground; apply it to the stem of vines attached to trees
Uneven-aged management	Mature stands	Cut vines growing in tree crowns before, during, or after harvest

Response of herbaceous species

Generally brushing provides only short-term control of competing herbaceous vegetation since only the above-ground portion of the plant is removed and many grass and herb species are able to resprout rapidly from extensive root systems (Hart and Comeau 1992). Repeated cutting during the same growing season may be necessary to achieve acceptable levels of control.

Selectively applying herbicides

Herbicides are chemical substances used to suppress or kill undesirable plants by damaging them directly through contact, translocation, or interruption of their normal growth process (Ahrens 1994). For individual tree control, selective herbicide application can be highly species selective, environmentally safe, and cost effective. Unlike broadcast herbicide applications and/or controlled fire, use of selective herbicides allows targeting of just undesirable species. Successful application of selective herbicide treatments depends upon the selection of the appropriate herbicide, application rate, timing, method and correct application.

Five herbicide products, of the 20 registered for forestry use, are most commonly used in Canada (McLaughlan *et al.* 1996), but only three of these are registered for individual woody plant treatment. Excepting soil-active herbicides, a list of herbicides registered for forestry use, their permitted uses, and their advantages and limitations are provided in **Table 8.1.3**. Each of the three registered herbicides profiled in **Table 8.1.3** is designed to control vegetation, but differs in its mode of entry and action, target species and application directions.

Soil-active herbicides (e.g., simazine and hexazinone) are not recommended for use in natural forest stands in southern Ontario because they can kill or cause injury if applied within the root zone of sensitive species.

For some herbicides and applications a carrier, usually an oil, is required to improve effectiveness.

Herbicide use requirements

The application of herbicides should only be carried out by properly trained, licensed and knowledgeable personnel. In Ontario, people applying pesticides must be licensed, or be working under the supervision of a licensed exterminator. Agriculturists applying pesticides must be certified through the Grower Pesticide Safety Course. For more information contact the Pesticides Officer through your local Ministry of Environment Office. For information on obtaining your Grower Pesticide Certificate, call the Ontario Pesticide Education Program at 1-800-652-8573. For more information on obtaining your Exterminator's license call 1-888-620-9999.

Herbicides must carry a manufacturer's label and be used according to the instructions on the label. The label must state the chemical and trade name of the herbicide, its composition and form, its concentration of active ingredients, the net weight or volume, and recommended precautionary measures. Other information on the label includes the vegetation controlled, directions for use, emergency phone number, instructions for safe application, storage, disposal, and spill treatment. Always read and follow herbicide label instructions carefully. It is illegal and possibly hazardous to use herbicides in any manner other than that specified on the labels.

Table 8.1.3: Comparison of permitted ground applications, advantages, and limitations of three commonly used herbicides registered for individual woody plant treatment (adapted from McLaughlan *et al*. 1996).

Active Ingredient	PCPN #[1]	Trade Name	Permitted Individual Woody Plant Treatment			Advantages	Limitations
			Basal	Cut-stump	Injection		
Glyphosate	19899	Monsanto <u>Vision</u> Forestry Herbicide		✔	✔	• Very effective on most annual, perennial, and woody species • Completely biodegradable, does not leach and cannot accumulate in the food chain	• Results will be poor on plants that are stressed or damaged due to their reduced ability to take up and translocate the herbicide • Rain falling on treated vegetation within six hours following treatment will reduce effectiveness
		Monsanto EZJect Herbicide capsules		✔	✔		
Triclopyr	22093	Dow AgriSciences <u>Release</u> Silvicultural Herbicide	✔	✔		• Allows removal of shrub and tree species while maintaining a grass cover on all right-of-ways • Can be applied in the dormant season, depending on snow depth, using basal stem treatments	• Most grasses are tolerant to triclopyr

[1] **Pesticide Control Product Number**

Table 8.1.3: *continued*

Active Ingredient	PCPN #[1]	Trade Name	Permitted Individual Woody Plant Treatment			Advantages	Limitations
			Basal	Cut-stump	Injection		
2,4-D (amine)	16994	Dow Formula 40F Forestry Herbicide		✓	✓	• Available as either an amine or ester formulation • An economical means of controlling many woody species and herbaceous broadleaf weeds • Less expensive than other herbicides • Allows removal of shrub and tree species while maintaining a grass cover on all right-of-ways	• The ester formulation can move off site if subjected to temperatures greater than 32°C and can even move in lower temperatures due to the thermal characteristics of the vegetation surface • Does not control grasses or sedges • Resprouting is a problem and subsequent release treatments may be needed • Not effective on maple or oak species
	16995	Clean Crop Forestamine Liquid Herbicide for Forestry		✓	✓		
	18067	Clean Crop Sure-Shot 500 Liquid Herbicide		✓	✓		
	18075	Clean Crop Sure-Shot Forestamine		✓	✓		
	18113	Sanex Amine 500 Forestry Herbicide		✓	✓		
	11441	Van Waters and Rogers Guardsman 2,4-D Amine 500 Liquid Weedkiller		✓	✓		
2,4-D (ester)	15981	Dow Esteron 600 Forestry Herbicide	✓	✓	✓		
	9561	Clean Crop 2,4-D Ester 500 Herbicide	✓	✓	✓		
	16675	Clean Crop For-Ester E.C. Forestry Herbicide	✓	✓	✓		

Mode of entry and action

Depending on the herbicide, the mode of entry and action will vary. Foliar-active herbicides are typically liquids applied over actively growing plants. Deposits of the liquid are absorbed either through stomatal openings or directly through the cells of the leaf surface. The herbicide is then translocated through the phloem to the roots. Foliar-active herbicides are more suitable for most vegetation management in southern Ontario forests because they permit managers to apply the herbicide only to unwanted vegetation, thereby maintaining most of the native ground cover.

Soil-active herbicides can be applied as liquids or solids (e.g., granules). The herbicide in soil solution enters the plant through the roots and is translocated through the xylem in the transpiration stream to the leaves. Soil-active herbicides, for example, simazine and hexazinone, are not selectively applied to unwanted vegetation, and hence are not recommended for crop-tree release. Both are more appropriately used for site preparation and seedling release treatments, primarily for plantation establishment on old field sites.

Herbicide applicators

Several types of herbicide applicators are commercially available. Those most appropriate for individual tree control and/or control of invasive exotics are described in the following.

Utility-type sprayers

Utility-type sprayers are readily available at hardware stores. These sprayers are adequate for treating small numbers of stems because they are labor intensive. They have often been used to selectively deliver herbicide in either hack-and-squirt or cut stump (of small diameter stems) applications. Ensure that the sprayer has chemically resistant seals and delivers a consistent volume of liquid. Knowing the volume of liquid delivered with each squirt is necessary for calibrating the amount of herbicide to be used (Mallik *et al.* 1997).

Backpack sprayer

Backpack sprayers have been used for directed foliar, basal, and stump treatments to release crop trees from unwanted competing vegetation. Common sprayer brands include Swissmex SPI and Solo backpack sprayers. For foliar applications, a TeeJet 8003E flay spray tip (or a similar tip) is used. For applying herbicide to cut stumps, straight stream, cone or flat fan nozzles are recommended. These can be obtained from most farm or hardware stores.

Herbicide applicator equipped brush saw

Herbicide applicators (e.g., the Sproutless Applicator) that attach to a brush saw are also available. The operator presses a button to release a small amount of herbicide to the top of the stump as the stem is cut. This ensures that herbicide is being applied simultaneously and directly to the cut stump and that no stumps are left untreated. For treating large areas or areas with a high density of stems that require treatment, this method is much less labour intensive, provided that equipment malfunction time is minimized. The Sproutless Applicator is available from Standish distribution (819/875-3386).

Encapsulated injection system

Encapsulated injection systems have the herbicide packaged in a capsule; there are no chemicals to mix or measure and the operator never comes into contact with the herbicide being used. The most commercially available system for injecting encapsulated herbicide is the EZJect® lance, developed by Monsanto, but now owned by Odom Processing Engineering & Consulting, Inc. and available in eastern Canada through Standish Distribution (819/875-3386). It is a metal aluminum tube just over 1.5 m long that weighs 4.5 kg. The bottom end features gripping teeth and a spring loaded injection assembly. The EZJect lance is prepared for use by loading it with pre-made plugs of herbicides encased in brass .22 caliber casings known as capsules. It can accept up to 400 capsules at a time. Reloading is simple and can be easily done in the field under any conditions, including heavy downpours. Each lance comes with a knapsack that holds 2400 capsules for convenience in the field.

Herbicide application techniques

Techniques to promote desirable native hardwood species include low-volume basal bark application, cutting followed by treating the stumps with herbicide (cut stump), and stem injection. They are effective and appropriate for selectively controlling unwanted vegetation in southern Ontario forest stands. Each of these techniques is discussed in the following. Foliar treatment is also presented, specifically for treating herbaceous invasive exotic species in the forest understory.

Low volume basal bark

Spraying or painting or swabbing the lower portion of tree stems with herbicides has been a long established practice for controlling vegetation in rights-of-way and utility corridors (Holt 1989). It is an effective method for selectively treating small stems (i.e., less than 10 cm in DBH), because it uses much less herbicide than broadcast foliar treatments and has less risk of having negative impacts on other non-target vegetation. Basal bark treatments are less expensive than injection treatments. Productivity averages 1 to 2 ha per day, depending on stem density.

A backpack sprayer is used to deposit a small volume of concentrated spray mixture (compared to foliar treatments), on the bark of the stem. The spray is adsorbed through the bark into the tree. The stem does not need to be cut with this treatment. Triclopyr and 2,4-D(ester) are the only herbicides that can be applied in low volume basal bark applications (**Table 8.1.3**). The herbicide mixture contains 20 to 30 % herbicide in an oil carrier. Mineral oil is preferable to diesel oil because it has no odour.

Low volume basal sprays can be applied at any time during the year because the oil carrier prevents freezing, but the higher herbicide rate should be used for dormant-season applications. For some species, application during the growing season (May-August) may achieve more effective control. Better efficacy is also achieved when the bark is dry. Triclopyr will separate from its oil carrier if applied to a wet surface.

There are three application techniques: streamline, one-sided low volume, and thinline.

Streamline basal bark

In the streamline basal bark herbicide application technique, a 20-30 % herbicide solution is mixed with mineral oil and applied using backpack sprayers equipped with flat fan 2503 nozzle, according to label directions. The flat fan nozzle of the backpack sprayer is directed to spray stems at a height ranging from 30 to 50 cm above the ground. On stems that are less than 8 cm in diameter, sufficient spray is applied to form a 5 cm band on one side on the stem. The objective of the application is to enable the spray to run down the stem, spread out, and encircle the stem within 30 minutes. If the herbicide solution does not completely encircle the stem, then the untreated cambium will not translocate the herbicide to the growing parts it services and the tree, or parts of it, will continue to survive.

Use of the streamline method for basal bark treatments produces better results when applied by experienced applicators. Applicators must ensure that enough of the herbicide is sprayed so that wetness completely encircles the stem. If treating coppice, all stems in a clump must be treated. For stems greater than 8 cm in DBH, both sides of the stem must be treated. Old or rough bark requires more spray than young or smooth bark (Gaetan Mercier, Dow AgriSciences 1997**,** personal communication).

One-sided low volume basal bark

A more reliable basal bark application technique is the one-sided low volume (OSLV) method. The OSLV method requires less stringent application and delivers more product to the stem to ensure reliable control (Gaetan Mercier, Dow AgriSciences 1997, personal communication). A 20 to 30 % herbicide solution, mixed with mineral oil, is applied with the same equipment used for the streamline method. The basal parts of at least one side of a stem (i.e., the lower 30 cm, including the root collar) are sprayed until thoroughly wet, but not to the point of runoff. Like the streamline method, all stems in a coppice clump must be treated to obtain good control. The OSLV method is effective on stems that are equal to or less than 15 cm in DBH.

Thinline basal bark

Undiluted herbicide is applied in a pencil-thin stream to cover the entire circumference of the stem. Stems less than 3 cm in DBH only need to be sprayed on one side. This is a low-volume technique that is quick to use.

Cut stump

Sometimes cutting down unwanted trees is preferable, especially in high-use recreational areas where girdling trees may result in future safety hazards. However, for species that are able to reproduce by stump sprouting or root suckering, there is a high probability that the stump will sprout following cutting. Stump sprouts may constitute important competition if allowed to develop too close to crop trees (Holt 1989). Therefore, depending on the autecology of the species being controlled, cut stump herbicide treatments are sometimes required to reduce sprouting and root suckering, especially in open sunlight conditions.

Cut stump is the application of herbicide to the cambium layer of the stump immediately after cutting. On small stems, the entire surface is usually treated while large stems require a wetting (by the herbicide) of only 5 cm in from the bark. For small stems, cut stump treatments use less herbicide than broadcast foliar treatment, and minimize negative effects to non-target native vegetation (Mallik *et al.* 1997).

Herbicides that can move into the stump and translocate efficiently are recommended for cut stump applications. For example, triclopyr as a 30 % solution in mineral oil has been found to be effective on both small and large stems. Glyphosate can also be effective, but application of this herbicide to the cut stump must be made within 5 minutes of cutting the stem (Monsanto 1994). Even when using triclopyr, the time between cutting and herbicide application should be kept to a minimum, and not exceed 2 hours since cutting. Rainfall immediately after treatment may wash the herbicide off the stumps (Mallik *et al.* 1997).

Cut stump applications can be made year round, but summer applications (May to August) using triclopyr have been most successful. Cut stump treatments should not be applied in the spring and fall to species that flush the herbicide off the cut surface during sap flow (e.g., sugar maple, white birch), since effectiveness will be reduced (Mallik *et al.* 1997).

Cut stump treatments can be applied with dabbing or spray equipment following cutting, or at the time of cutting if using an herbicide applicator equipped brush saw. Applications made during cutting may save time but distribution of the herbicide on the stump may be inadequate to provide control. Applications made after cutting with utility-type or backpack sprayers usually provide complete coverage because the operator can direct the spray precisely. Applications with triclopyr should cover the cambial layer and sides of the stump. The treatment area should be sprayed until wet. Cut stump treatments are most effective when the application is made to a clean stump surface that is free from sawdust, dirt or damaged tree fibers (bark tears) as these may restrict the flow of herbicide into the stump (Mallik *et al.* 1997).

Stem injection

EZJect®

For small areas with low numbers of stems to be treated and/or for environmentally sensitive sites, the use of the EZJect lance offers little chance of environmental contamination or worker contact with concentrated herbicide. The lance (loaded with capsules) is easy to carry, and can accompany natural resource managers on routine site inspections. It is particularly useful for treating sparse invasions of woody invasive exotic species (e.g., buckthorns).

The lance is operated by first putting the gripping teeth against the trunk of the tree stem to be treated. With a fast thrust of their arms, the operator pushes the injector nose into the base of each tree to be treated leaving a casing buried in the cambium of the tree trunk.

The EZJect lance provides several advantages:

- It is convenient to use, compared to traditional girdling or frilling methods where operators need to switch tools back and forth between hatchet/drill and the herbicide applicator

- It is very safe for the operator.
- There is no risk of herbicide drift to sensitive, non-target vegetation.

The drawbacks of the EZJect lance are:
- It is hard to use in densely overgrown or tangled areas because it keeps getting snagged on branches. However, a smaller, 1.2 m version is available.
- The lance and the herbicide capsules are expensive. Discount prices apply for purchases of larger quantities. For larger areas with a greater number of stems per hectare to be treated, the cost of the capsules becomes prohibitive.
- Older models of the lance may jam, causing delays.
- Operators must carry enough capsules to treat all required stems. Very small diameter and coppice stems are more difficult to inject.

Capsules are available with either triclopyr or glyphosate herbicide. More information on species controlled by the two herbicides that are available in capsule form for use in the lance can be obtained from http://www.ezject.com/

The number of capsules to be injected into the base of the tree stem varies with stem diameter. The manufacturer's recommended rate is one capsule per 5 cm of DBH for glyphosate. The water-soluble herbicide enters the sap of the tree and subsequently kills the stem.

EZJect applications should be done during the growing season to ensure translocation of the herbicides. Application can be made in the rain.

Hack-and-squirt
This method injects the herbicide with an axe or hatchet. For application, a right-handed person should grasp the hatchet in the right hand and strike the tree about waist high, cutting through the bark into the sapwood. Space single cuts evenly around the tree trunk, with the spacing between cuts as recommended by the product label. With the squirt bottle in the left hand, apply the herbicide to the cut when the hatchet is removed. The squirt bottle should have chemically resistant seals and produce about 1 ml for each pull of the applicator handle. A left-handed person would hold the hatchet in the left hand and the squirt bottle in the right hand.

Direct foliar spray

In the context of managing natural forest stands in southern Ontario, this technique is primarily for control of herbaceous invasive exotic species such as garlic mustard. Caution must be taken to direct the spray onto the target foliage and away from desirable native vegetation. The herbicide is usually applied with a backpack sprayer and a hand spray gun using a flat or an adjustable spray tip.

For annual species, early season application should be made after full leaf-out of the target species (i.e., well before seed set). For perennial species, late season applications should be made before fall color appears, preferably before the first fall frosts, to permit translocation to roots. The Extension Note *Using a Backpack Herbicide Sprayer to Control Weeds* provides more information on the direct foliar spray technique.

Vegetative response to herbicides

Table 8.1.1 also provides a summary of woody plant species responses to treatment with three herbicides, glyphosate, 2,4-D, and triclopyr.

Recommended control treatments for most problematic invasive exotics

When natural landscapes are disturbed they are more likely to be colonized by rapidly growing invasive species. Disturbances such as those caused by road and trail building, ditching, and housing developments adjacent to or near a woodlot will provide opportunities for these species to invade.

The diversity of undesirable plant species and their growth rates are greater in this part of the province than farther north. Therefore managers should learn to identify some of the more troublesome species so these can be removed as soon as they see them on their property or inform their neighbors about them. Non-native and aggressive species such as buckthorn, honeysuckle, and garlic mustard are easier and less expensive to control if spotted and removed early on from a woodlot and adjacent areas.

To control invasive exotic species it is much easier to prevent their establishment rather than try to eliminate them once established. Treating invasives for removal during tree marking and/or harvesting operations may be convenient if harvesting activities are scheduled for the woodlot. Some options for removing exotic species include selectively applying herbicides, hand-pulling, cutting, and burning.

To prevent invasive species from becoming established, landowners and resource managers are encouraged to remove invasive exotics before they become a problem. If the woodlot is at risk for invasion by exotic species, for example, due to recent disturbance, or because these species are established in adjacent or nearby woodlots, extra care is suggested. If identification of the species is in doubt, the plant's identity should be confirmed by a knowledgeable individual and/or by consulting appropriate field guides. *Newcomb's Wildflower Guide* (Newcomb 1977), *Shrubs of Ontario* (Soper and Heimburger 1990), and *Ontario Weeds* (Alex 1992) are three such guides.

Some preventative measures include:

- Maintain crown closure in the woodlot to provide light levels that are opposite to the invasive exotic's habitat preference. For example, group selection should not be considered in forest stands with large exotic buckthorn or honeysuckle populations (unless control of these species is also planned), as the increased light levels may stimulate their growth into the canopy.
- Keep roads, skid trails, landings, and other disturbances (e.g., dumping) to a minimum.
- Require harvest operators to power wash logging equipment before arriving at the site.
- Monitor the woodlot on a regular basis.

Table 8.1.4 presents information about the habitat, reproduction and dispersal, and recommended control measures for several common invasive exotic species that occur in southern Ontario forests.

Table 8.1.4: Vegetation management treatments for commonly encountered invasive exotic species in southern Ontario forest habitats.

Species	Habitat	Reproduction and dispersal	Recommended method of control
Barberry	• Damp lowlands to dry roadsides and waste places • Shade tolerant, often found in forested habitats	• Prolific reproduction from seeds, rhizomes or layering	• Handpulling is effective for small populations • Mowing/cutting will control spread but not eradicate • Control is best achieved by applying glyphosate or triclopyr to foliage (2%) or cut stumps (25%)
Smooth Brome	• Roadsides, forests, prairies, fields, and lightly disturbed site, not tolerant of highly organic soils	• Reproduce by seed and rhizomes • Germination primarily occurs in early spring, but can also occur in early autumn if soil moisture is adequate • Readily expands population base vegetatively and aggressively, sod-forming • Individual rhizomes reportedly have longevity of 1 year	• Spring burning is the most widely used tool to control cool season grasses, however, it may be necessary to burn annually for several years • Burning most likely to be effective at “boot” stage, when flowering head still enclosed in sheath • Cutting at least 4 times per season has been found to be effective • Glyphosate has been effectively used to shift dominance from cool to warm season (native) grasses • Itonidid midges, specifically bromegrass seed midge, and chalcid flies are predators of maturing seeds
Glossy and Common Buckthorn	• Open areas, disturbed forest edges, ravines, forests, wetlands • Will germinate in full sun or shade • Shade tolerant under forest canopy • Needs light to be released into canopy	• Prolific seed production, seed dispersed by birds • Produces seed at very young age • Root suckers, resprouts vigorously from cut stumps • Able to form persistent seed bank	• Best control achieved by cutting after peak flowering (May-Jul.) followed by selective glyphosate treatment (30% solution) to either cut stumps (immediately after cutting) or resprouts (approx. 6 weeks after cutting) with a wick applicator (Strobl 1999) • Basal bark application with as little as 8% triclopyr (Strobl 1999)

Table 8.1.4: *continued*

Species	Habitat	Reproduction and dispersal	Recommended method of control
Dame's Rocket	• Open areas, disturbed forest edges	• Perennial • Wind borne seed	• Apply glyphosate at onset of flowering
Dog-strangling Vine	• Fields, hydro corridors, disturbed forest edges, ravines • Not tolerant of heavy shade	• Prolific seed production, seed wind-dispersed over long-distances • Able to regenerate from root crown pieces	• Light infestations can be controlled by removing plants including root systems • Larger infestations can be controlled by applying glyphosate twice during the growing season, at the onset of flowering and 2 to 3 weeks later; follow-up treatments will be required to eliminate surviving plants and new seedlings • Mowing/cutting and burning are ineffective
Garlic Mustard	• River floodplains, forests, roadsides, wooded edges • and forest openings • Tolerates full sun to full shade, prefers partial canopy	• First half of 2-year cycle garlic mustard is a rosette of leaves • In second spring, rosettes develop rapidly into mature plants that flower, produce seed and die by late June (at which time it can be recognized only by the dead stalks and dry, pale brown seedpods that may hold viable seeds) • A single plant can produce thousands of seeds, that scatter as much as several meters from the parent plant • Long-distance dispersal is most likely aided by humans and wildlife (e.g., deer)	• Control efforts should be targeted at preventing seed production • Once established, 2-5 years of treatments will be necessary to deplete seed banks • Small, young infestations and/or isolated populations, flowering stems can be cut at ground level to prevent seed production • Glyphosate provides effective control for heavy infestations when applied in mid-spring; in the fall glyphosate can be applied to rosettes, as long as the temperature is above 10^{o} C • Burning stimulates germination of stored seeds and seedling growth, and must be conducted annually for 3-5 years to achieve effective control • Four beetles are currently being investigated as biocontrols, may be available within 5 or 6 years

Table 8.1.4: *continued*

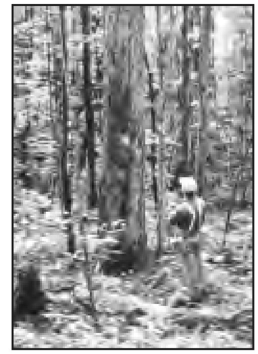
Species	Habitat	Reproduction and dispersal	Recommended method of control
Honeysuckle Species (Exotic)	• Disturbed successional communities, wetlands, woodland edges, partially closed forests • Moderately shade tolerant, take advantage of canopy gaps	• Prolific seed production, berries highly attractive to birds, which widely disseminate seeds across the landscape • Sprouting occurs in established populations	• In less shaded forest habitat, where plants are less resilient, repeated clipping to ground level (at least once annually) may result in high mortality • Well-established stands can be treated by cutting stems to ground level and then applying a 25% solution of glyphosate or triclopyr to the cut stems
Japanese Knotweed	• Damp to dry soils, along streams and rivers, in low-lying areas, waste places, old homesites • Can tolerate full shade, high temperatures, high salinity and drought	• Spreads primarily from rhizomes, pieces distributed by water and in fill • Seeds distributed by wind, water and in fill	• Digging is not recommended because it tends to spread rhizome fragments • Most effective method of treatment is cutting stems 2-3 times/season, followed by foliar applications of 2% glyphosate in the fall and following spring • Repeated stem cutting may be effective
Norway Maple	• Wooded ravines and forest edges • Very tolerant of shade as seedlings • Saplings require more sunlight to grow into canopy, and are able to tolerate full sun • Tolerates infertile and compacted soils, and atmospheric pollution	• Produces abundant seed, annually • Seed wind-dispersed over wide distances • Produces samaras with 2 full seeds that are heavier and have higher viability than those of sugar maple	• Pulling with weed wrench is easy for seedlings < 3 cm DBH, more difficult for those with DBH of 3-8 cm • Gradual removal of a dense canopy may stimulate germination of native species and/or release of older sugar maple

Sources:

- Natural Areas Association. 1992. Compendium on exotic species, Articles 1-43.
- Various Exotic and Invasive Species Websites, including:
  - Invasive Plants of Canada Project - http://infoweb.magi.com/~ehaber/factfoil.html
  - Invasive Alien Plant Species of Virginia - www.state.va.us/~dcr/dnh/invphrag.htm
  - Northern Prairie Wildlife Research Centre - www.npwrc.usgs.gov/resource/othrdata/explant/phalarum.htm
  - Plant Conservation Alliance (Washington, D.C.) - www.nps.gov/plants/alien
  - Tennessee Exotic Plant Management Manual - www.state.va.us/~dcr/dnh/invlyth.htm
  - Great Plains Organization - www.greatplains.org/npresource/othrdata/exoticab/effirham.htm

8.2 TREE MARKING

by Mike Walsh and Scott Reid


S. Reid

Introduction

Tree marking is the mechanism that facilitates the regulation of partial cutting silvicultural systems (Anderson and Rice 1993). Stand analysis and prescription setting efforts may be wasted if marking is poorly done. Tree-markers have a unique responsibility in stand management because they are the only people who must examine an entire stand by walking through it and assessing every tree.

Considerable training and experience are necessary for tree-markers to become proficient. McLean (1976*b*) has outlined some of the knowledge required, including:

- species identification
- silvical characteristics of species
- comprehension of stocking levels and structural types
- appreciation of tree quality and vigor, including use of an acceptable tree classification system
- recognition of defect characteristics and indicators
- familiarity with site and land features
- appreciation of commercial values of species, products, and grades
- appreciation of wildlife habitat, biodiversity, and other ecosystem values.

Evaluation of this knowledge is best achieved by testing markers' abilities on permanent test plots of known stocking and structure.

The job of the tree-marker is to apply the prescription to the best of their ability, to the conditions they encounter as they walk the stand. This is important because stand and site conditions vary, affecting stocking levels, species composition, size class structure, and forest health.

Supervision

One person should assume the role of the crew leader and be responsible for:

- helping the forester, supervisor, or landowner find the stands to be marked and collecting required data
- securing maps, aerial photographs, prescriptions
- reserving vehicles and other essential equipment
- supervising the marking tally and checking to ensure proper prescription application and its documentation
- establishing the marking lines and ensuring full coverage of the prescribed area
- modifying or changing the prescription in unique or unusual local situations and reporting such variances to the appropriate people.

Safety

The supervisor should ensure staff are familiar with the following:

- safe working practices
- Material Safety Data Sheets (e.g., for tree marking paint)
- Ontario Health & Safety Act (OHSA)
- operation and maintenance of equipment
- safety equipment
- hazards (e.g., snags)
- CPR and First Aid.

Field techniques

Pre-mark inspections

It is important to visit the area to be marked ahead of time, preferably with both the author of the prescription and the landowner. The purpose is to learn more about the stand and discuss the prescription and management objectives, as well as the areas of concern (AOCs) for the stand to be marked (**Table 4.4.1).**

Boundaries

All boundaries and reserves should be marked first, including boundaries that will mark areas of concern (e.g., seepage areas, woodland ponds, stick nests, important wildlife foraging areas or travel routes).

Crew organization

The size of the crew will depend on the size and location of the area to be marked, access to the stand, time and budget constraints, and the nature of the tree marking prescription. Other considerations include transportation and accommodation arrangements and provision of maps and aerial photographs for markers. Also these people should have sufficient time to discuss the prescription with its author, to ensure that it is clearly understood by them.

Once in the stand, there are other considerations that improve marking efficiency. Markers should not work too close together or too far apart. In dense forest cover, workers should help each other to identify dead tops, diseased trees, and tree cavities and other non-timber values. It may require more than one person to see the entire bole of a tree. Each marker should stay slightly ahead of the person behind him in the row. The last marker in the crew should mark so that all markers can all follow his/her line back to their starting point.

Paint color

The marking prescription usually prescribes the color of paint that will be used. Normally the following colors are used:

- Yellow or orange for trees to be removed; note many markers and loggers prefer orange for its higher visibility.
- Red for marking boundary lines and reserves (i.e., no-cut zones).
- Blue for trees to be retained (e.g., crop or wildlife trees).
- Black or grey to cover up marking errors.

Tree-markers must realize that many landowners are sensitive to the use of paint in their woodlot. For example, many may prefer that markers use only orange paint to mark trees that will be removed and refrain from marking any other trees, since even those with blue paint will be an eyesore to them for many years. Similarly, markers are encouraged to carry cans of both black and grey tree marking paint (used to cover orange paint marks) to cover up mistakes, and adjust the color to better match the bark.

Types of marks

Trees are commonly marked in two places:

1.Top mark

Spray completely around the tree or at least mark the tree on three sides at eye level. Marks should be placed to face the next unmarked strip. In southern Ontario the top marks are often symbols that indicate products (i.e., dots to indicate saw- or veneer logs, slashes to indicate fuel- or pulpwood).

2. Butt mark

Preferably place the butt mark in a seam or depression at the base of the tree (root collar) where it would be difficult to knock the mark off with a skidder tire. Butt marks permit auditors to determine if a cut tree was originally marked for removal.

Volume tally

When net volume estimates of trees marked for cutting are required, the species, DBH, merchantable length, and current tree quality class (e.g., as outlined in Morawski *et al*. 1958) should be recorded. Net merchantable volume can be calculated using volume tables such as Ontario Log Rule, Form Class 79 **(Table C-4)** and applying individual cull factors for the various tree classes (**Appendix E**).

Quality assurance

Quality assurance is the process by which a completed or progressing tree marking assignment is inspected to ensure that it meets accepted standards for implementing a prescription and employing designated procedures. Quality assurance provides information about the:

- adequacy of prescription implementation
- acceptability of the field procedures
- completion of contract obligations in the case of private-sector marking services
- suitability of the marking instructions
- identification of difficult tree marking situations where more education and training may be necessary.

It should be emphasized that the process is not designed to test individuals or groups of tree-markers, but to provide forest stands with the correct application of the prescription.

Parameters that should be examined during quality assurance include:

- recognition and consideration of all boundaries, AOCs, and non-timber values that occur in the marking area
- realization of prescription targets (e.g., basal area levels, number of trees per hectare)

- correctness of tree selection for retention or removal, based on guidelines set out in the prescription (e.g., species priorities, spacing guidelines, tree quality class, structural goals)
- visibility, location, and manner of paint application
- proper adjustment for unusual conditions encountered (i.e., change in marking prescription).

There is little published or recorded data concerning the levels of precision that these parameters should meet. As a result, most tree marking assessments done in the past have been subjective.

Preliminary results from a quality assurance study conducted in Algonquin Park in which data were recorded in stands marked for either selection or shelterwood systems, indicate that basal area targets were marked to within 6 % of prescribed stand levels. On average, less than 9 % of individual trees were incorrectly marked (Rice and Anderson 1988). These results suggest that incorrectly marked basal area (according to prescription) should not exceed 2.3 m^2/ha on average for selection marking, and 1.4 m^2/ha on average in shelterwood marking. While these results are from a single study, they provide an indication of the relative precision that may be anticipated in tree marking. Different locations in Ontario may dictate different acceptable levels, depending on location, site and soil conditions, size of the operation and its objectives, season of marking, and the experience of markers.

In order for quality assurance to provide information on stand-marking operations and help to determine knowledge gaps, permanent records of the tree marking activities in each designated area should be maintained. This information will:

- provide information that will assist in determining future management decisions
- identify locations of unusual forest conditions that may require future assessment (i.e., tree decline)
- provide a way to monitor the adequacy of tree marking for individual crews or crews in different stand situations, seasons, or regions, in order to improve effectiveness and consistency.

Since tree marking as a means of implementing and controlling prescribed partial cutting in tolerant hardwood forests is becoming more important, tree marking certification procedures and provincial standards, modified as necessary for local conditions, should be established. Quality assurance procedures are one way to maintain the performance quality expected from certified markers.

Limited quality assurance (e.g., by audits) is conducted on private or public lands in southern Ontario. To encourage sustainable forest management, managers should encourage self-auditing. Landowners and/or managers could try to make constant prism sweeps and keep a tally of basal areas by size class as they walk the stand. Forest managers of large tracts of public forest should consider implementing a voluntary audit of their tree marking performance (as is done on public/Crown land in central Ontario).

8.3 CAREFUL HARVESTING FOR CUT AND SKID CREWS


E. Boysen

by Chris Gynan and David Bland

What is a cut and skid crew?

Although there are several ways to remove timber from the forest, in southern Ontario, most of this work is done by cut-and-skid crews. Cut-and skid crews use chainsaws to cut trees, mainline cable skidders to skid logs to the landing, and possibly a small front-end loader or skid steer for piling logs at the landing. The skidder usually carries a 30-meter cable. A loader is ideal because it serves as an alternative to a landing, but it is not normally used. A grapple skidder is another option but it is not recommended because it causes more damage since it is larger and must be driven to the base of each tree.

A cut-and-skid crew usually consists of two workers: a cutter or feller who uses a chainsaw to fell, limb, and top the trees; and a skidder operator who skids the logs to the landing. Either the feller or skidder operator bucks the logs (i.e., cuts them to length) once the landing is full or at the end of the day. Tree lengths are bucked to optimise log value, then scaled, sorted and piled according to species, product, and destination.

Why careful harvesting is important

Careful harvesting is extremely important because it helps reduce risk of injuries to forest workers and it minimizes damage to the site and stand. Damage jeopardizes the future economic value and reduces the growth rate of the injured trees. Wounds permit the entrance of diseases that can increase the chance of decay by more than 50 % within 20 years following the harvest. This results in a reduction in future volumes and quality leading to decreased lumber grades and higher mortality rates (Nyland 1994). Wounded trees tend to be less vigorous and have a reduced ability to heal themselves. They will also contribute less to the overall growth and development of the forest stand.

Trees that remain after harvest will not only produce the next supply of wood products, but will also produce seeds, protect the established young tree growth and other vegetation, and provide site protection (e.g., from soil erosion) and valuable wildlife habitat. Therefore they must be protected from harvesting damage.

In summary, careful harvesting

- helps to protect the complex relationships among forest life forms and the air, water, and soil
- improves the growth rates and quality of the residual stand
- minimizes damage to trees destined for market and residual crop trees that are expected to increase in size and quality until some future harvest date
- helps to ensure sustainable and profitable harvests of high quality timber/forest products for the future
- increases the chance of selling the firewood and meeting silvicultural objectives. For example, a woodlot that has tree tops layered in unorganized piles, tops felled into the trails, or rutted trails will be more difficult to sell to a firewood operator.

- helps to protect regeneration and may encourage understory regeneration of some tree species because the skidder will expose mineral soil that can increase germination
- can help to protect wildlife and habitat
- reduces disturbance to sensitive species, especially during the critical breeding season, nesting, and growing season (plants)
- maintains a positive visual impression about logging operations, and discourages unfavorable stereotypes and opinions about timber harvesting
- encourages good forest stewardship
- helps to avoid injury to forest workers
- reduces soil compaction and rutting as a result of indiscriminate trail building
- reduces disruption of drainage patterns and internal soil-water flow.

Special attention must be paid to the layout of forest roads and trails and activities such as felling and skidding to avoid soil erosion, compaction, and other negative impacts to water quality, soils, vegetation, and sensitive species.

Avoiding injury to workers

Timber harvesting is a potentially hazardous activity, and even an experienced, careful logger is occasionally injured (Van Ryn and Lassoi 1987). Therefore worker safety should be the top priority. Often, accidents and injuries can be avoided through proper training. The Ontario Forestry Safe Workplace Association offers cutter and skidder safety training programs through the Ministry of Education and Training (MOET). In fact, workers engaged in logging operations must be certified through the MOET Mandatory Cutter–Skidder Operator Certification Program. The Professional Chainsaw Operation (PCO) course, offered by the Ontario Forestry Safe Workplace Association, is the accepted standardized chainsaw training program for certification under the Mandatory Cutter-Skidder Operator Certification Program in Ontario.

Impacts and types of damage to forests

1. Wounds to larger residual trees

Trees with more than one of the following types of wounds have a higher probability of becoming defective

1a. Bark abrasion

Harvesting operations can cause bruising, scraping, gouging, and bark removal. Usually gouging is more serious than bruising or scraping. Bark abrasion will trigger discoloration of the wood in the damaged tree, and possibly lead to decay. Both discoloration and decay reduce the lumber grade of a tree and its potential to produce high quality wood products.

How does it occur?

Bark abrasion and butt scarring occur particularly along skid trails. More than half of the damage to trees from harvesting occurs during skidding operations (Walsh 1980). Trees frequently show bark wounds when they have been forcefully struck by a felled tree or scraped by sliding logs or skidder tires. However falling trees cause relatively few bark abrasion injuries compared to sliding logs, especially along the lower bole.

Common causes of bark wounds include:

- the use of tire chains (that should only be allowed on the front (drive) tires of a skidder operating in winter)
- harvesting in the spring growing season (March to July, depending on location)
- poor skid trail layout
- failure to fell trees at an angle that permits easy access to them (i.e., 45° angle to the skid trail). Trees felled perpendicular to the trail must be hauled around corners, resulting in more debarked trees.
- the use of over-sized equipment (i.e., grapple skidder) skidding too many logs at once (i.e., load must not be wider than the skidder)
- skidding tree lengths that are inappropriate for the skid trail layout. Full tree length may be fine if the majority of skid trails are straight, but could cause excessive damage if there are frequent curves or corners. Skidding shorter tree lengths usually causes less damage.
- skidding lengths longer than 8 m (25 ft.)
- indiscriminate felling practices
- brakes that function poorly.

Importance of wound size and location

Wound size and its location on the trunk are important because they affect the likelihood of infection by disease or decay causing organisms. The larger the wound is, the greater the probability of infection. For trees from 10 to 31 cm DBH, wounds are considered to be a serious tree defect when they cover a surface area greater than the square of the DBH. For example a tree with a DBH of 20 cm has a major defect when a wound on it is larger than 400 cm^2 (i.e., 20 cm x 20 cm). All wounds larger than 1000 cm^2 (32 cm x 32 cm) are considered serious, regardless of tree size (Dey 1994). On sugar maple trees, wounds larger than 1000 cm^2 resulted in decay 50 % of the time, after 10 years (Dey 1994). The chance of decay further increases if the wound is located near the ground. Wounds in contact with the soil only need to be 60 % of the sizes previously mentioned, to be considered major (Nyland and Gabriel 1971). Soil organisms can easily infect an open wound when scars are within one meter of the soil surface. Serious wounds may kill the affected tree and can cause wood volume losses of 10 % or more before the next harvest (Dey 1994).

In short, larger wounds are more serious than small ones and wounds closer to the ground have more potential to be infected by disease and decay. However, wounds higher on the stem may have greater potential for volume and grade loss, as they will potentially harm more of the butt log. The bottom line is that efforts must be made to ensure logging practices are carried out in a way that eliminates most wounding.

Affected species

All tree species are subject to infection and decay following injury, but their resistance to infection varies. Yellow birch is more susceptible to decay than most other species in the tolerant hardwood forests. Exposure of 600 cm^2 (approximately 25 cm x 25 cm) of sapwood in yellow birch usually indicates internal decay (Dey 1994). Generally, wounds on yellow birch are considered major at 60 % of the size of serious wounds on other species.

Seasonal occurrence of bark abrasion

The incidence and severity of bark abrasion exhibits seasonal variation. In spring, as trees emerge from a dormant condition, the living cells behind the bark are thin-walled and flexible, making them especially susceptible to breakdown when subjected to impact. Ultimately this leads to bark slippage and eventual scar formation. Tree bark tends to be most sensitive to peeling and slipping between the months of April and July. Therefore, restricting timber harvest to the winter months will help to limit the severity of bark abrasion, but this does not mean that all damage can be avoided during this period (Nyland 1994). When this schedule is undesirable, at the very least, harvesting should be avoided in selection silviculture cut areas between early April and the end of July.

1b. Crown damage

Crown damage is a wound to the branch structure of a tree, often in the form of broken branches.

How does it occur?

Branches of residual trees sometimes break off due to impacts or entanglements with neighboring stems that are felled. This type of damage is a concern due to the loss of photosynthetic potential and the subsequent reduction in tree vigor that can impair tree growth and its ability to recover from other wounds such as bark abrasions. Also organisms can enter the main trunk of the tree and cause discoloration and decay, lowering the value of potential wood products. Among injured trees, one in three can become infected with disease (Dey 1994). Crown damage is greatly increased when harvesting takes place in the growing season. The mass of the crown is much larger due to the foliage and the limbs are very supple.

Importance of wound size

Branches larger than 8 cm at the base have a greater chance of becoming infected by disease than smaller branches (Nyland 1994). Infection tends to be even more serious when damage creates "frayed" stubs because of their affinity to trap and retain moisture (Anderson 1994*b*). Generally, trees are less vigorous and more likely to decline in health when more than 10% of the major branches are broken and dead (Dey 1994). Also larger wounds are likely to create hazardous limbs and lead to poorer crown development and form.

1c. Root damage

Root damage is a disruption to the healthy functioning of a root system. Damaged tree roots have reduced nutrient and moisture uptake, limiting the growth of residual crop trees and destabilizing them to wind and other forces. Root injuries also reduce tree vigor, thus decreasing the ability to recover from wounds. Root wounds are a cause of defect in the butt log (i.e., the bottom portion of the tree stem) that represents the majority of the volume of a tree and the log of highest value. These wounds are vulnerable to root-rotting fungi and sap streak disease that may eventually lead to the death of the tree.

How does it occur?
Root injuries occur when:

- equipment or logs scrape and tear bark from surface roots
- stems are jarred by machinery or by a felled tree, bending and pulling roots from the soil
- the ground around a tree is compacted by machinery, pinching and breaking roots
- ruts caused by skidders sever or wound root systems.

Importance of wound size.
When more than 25 % of the root system has been exposed or severed, the tree has a greater than 50 % probability of becoming infected, and will usually exhibit dieback within 10 years following injury (Nyland 1994).

Is species important?
Some species of trees are more susceptible to root damage, particularly those commonly found growing in lowland forests (e.g., red maple, silver maple, yellow birch, white cedar, and bur oak). These species tend to have shallow root systems that make them more prone to damage than upland species like sugar maple. Yellow birch is especially sensitive to root damage and may develop root rot within 4 years after wounding, with stain progressing into the butt log (Dey 1994). It should be noted however, that all species may decline or die if the critical feeding roots found near the surface are sheared off.

Beech primarily reproduces by root suckering that is usually caused by harvesting trees but also caused by vehicular traffic. To discourage this type of beech regeneration in a woodlot, use active trails and try not to drive over beech roots.

2. Damage to saplings and polewood

Most silvicultural activities are carried out with the ultimate goal of ensuring adequate regeneration. If large areas of existing young trees are lost due to poor harvest practices, the future of the stand is jeopardized.

Saplings are trees of less than 10 cm diameter at breast height (DBH); poles range from 10-24 cm DBH. In managed, uneven-aged forests, they tend to be relatively young and serve to regenerate openings where larger trees are removed. Unfortunately, they are often severely damaged or even destroyed during careless harvests. For example, in selection cut stands, 50 % or more of the trees injured during felling and skidding operations are saplings and pole-sized trees (Nyland 1994). Saplings and poles are most susceptible to breaking, bending, or tilting.

Since saplings and poles represent future sawlogs, the long-term sustainability of a forest stand is adversely affected by unnecessarily high damage levels to these younger stems. This is of special concern in selection management where the goal is to create and maintain an uneven-aged stand structure in which there are comparatively more trees in the smaller size classes (Nyland 1994; Dey 1994). Nevertheless, even with reasonably good harvest practices, approximately 15 % of the trees less than 13 cm in DBH may be destroyed when harvesting 30 % of the stems from the stand (Nyland 1994).

Some damage to regeneration is unavoidable during any harvest operation, including those done by using horses. However it can be reduced by careful operations and common sense, such as not skidding whole tops during firewood operations. Damaged trees can be either pruned or removed during a firewood operation. Grapple skidders should not be used. Trails can be located to avoid or minimize damage to regeneration.

3. Damage to other vegetation

In addition to damaging residual trees, harvesting can destroy tree seedlings, shrub, and herbaceous vegetation growing in the forest understory. Vegetation diversity within a stand benefits the entire forest ecosystem as well as its long-term health, and may even help to improve its resilience to disturbances such as windstorms, fire, pollution, and global warming. Damage to this other vegetation may not only degrade the forest environment, but could also reduce the potential for sustainable timber management. The amount of this damage will depend on stand structure prior to the harvest, timing of the harvest, and care taken during harvest.

How does it occur?

Understory plants may be disturbed by harvesting due to:

- surface disturbances causing uprooting and trampling
- addition of slash that causes smothering
- changes in microclimate causing poor growth and reproduction
- introduction of aggressive non-native plant species such as garlic mustard, transferred to the site on skidder tires or other equipment.

Tree skidding is more likely to be the cause of species loss than any other aspect of harvesting. Therefore it is important to carefully locate all skid trails and keep them to a minimum (Reader 1987).

Factors that control rate of species loss due to harvesting

Reader (1987) outlines three main factors that control the rate of species loss due to harvesting:

- the type of species
- its initial abundance
- the cutting intensity

Type of species

Although all species may be affected by harvesting treatments, during the winter months with snow on the ground, woody species are more affected than herbaceous species. This is because the living parts of woody plants are above ground at the time of harvesting while those of herbaceous species are below the surface where they are better protected from the harvesting activity (Reader 1987).

Initial abundance

Initial abundance of plants within the stand also affects their rate of loss. Those with small populations (i.e., only a few individual plants within the entire woodlot) are at greatest risk of disappearing. An entire population can easily be destroyed if it occurs in the path of a proposed road or skid trail. Frequently populations of such plants occur in clumps. By carefully laying out all roads and trails, their destruction can often be avoided. This is imperative when plants are vulnerable, threatened, or endangered (VTE) species because of the currently unknown ecological role of many of them in the forest ecosystem, as well as their value to the overall natural history of the area. Some species may be quite abundant within a stand but due to their sensitive nature, may almost entirely disappear if harvest operations seriously disrupt patterns of drainage or infiltration by sunlight. Consequently managers are advised to seek the advice of a competent botanist prior to building roads and skid trails. Wildlife inventories identify plants and animals found in a forest stand and should be conducted prior to harvesting (e.g., as part of the planning process before the silvicultural prescription is written). Significant species should be protected.

Cutting intensity

In general, the rate of species loss from the understory resulting from a harvest is directly related to the intensity of the harvest. Over the short-term, heavy harvests tend to disturb the site (e.g., soil compaction and removal, damaged vegetation, altered drainage patterns) and change the microclimate (e.g., increased penetration by sunlight and wind, greater temperature fluctuation and infiltration by rain water at ground level) more than light cutting. Careless harvesting can accentuate these changes and the concomitant loss of species through unnecessary damage to both the site and its vegetation.

4. Damage to soils and water quality

Harvest operations can damage soil and water resources by causing soil rutting, mixing, compaction, and erosion. These changes create less-favorable environments for plant growth and cause pollution in nearby streams or lakes. Water pollution caused by erosion has been shown to affect the abundance and functions of fish, amphibians, invertebrates, and aquatic vegetation (Woodley and Forbes 1997). Trout are extremely sensitive to sediment and thermal pollution (Georgia Forestry Commission 1999). Without proper measures to control erosion, soil may wash into streams and lakes, causing siltation that can reduce water quality and harm fish spawning beds and habitat for numerous other wildlife species. In Canada, damaging fish habitat is a Federal offence under the *Fisheries Act*.

Why does it occur?

The majority of soil and water quality problems happen as a result of the construction and use of truck roads, landings, and skid trails, particularly when these occur near shorelines of water bodies or on slopes. Bare soil exposed by road building is the major source of stream sediment from harvest operations. Roads normally expose soil on about 10 % of logged areas (Kochenderfer and Helvey 1989). Little soil exposure and erosion is caused by actual felling of trees.

How does it occur?

Compaction
Soil compaction is the loss of air space between soil particles, and is caused by disturbance and compression of the ground by harvesting machinery. Compacted landings and roads have restricted infiltration of rainwater and groundwater flow that increases surface runoff and promotes erosion. Runoff may also contain toxic materials from fuels and lubricants, further aggravating the problem of siltation (Georgia Forestry Commission 1999).

Compaction is more likely to occur during wet periods, particularly on fine- and medium-textured soils (e.g., fine tills). Coarse-textured soils (e.g., sands) and those with high organic matter content are less affected by compaction.

Rutting
On skid trails, especially where the soil is wet, tire ruts can form in the ground. Ruts channel water and cause severe erosion, especially as slope inclination and length increase.

If timing is appropriate, rutting can be avoided except on wet sites. Depth of rutting caused by skidding will vary depending on soil moisture and texture, tire width, machine load, as well as snow cover and whether or not the ground is frozen. In general, on main skid trails ruts deeper than 30 cm are excessive. Ruts on spur trails should not exceed 15 cm.

To reduce the likelihood of rutting, the ground should be dry or frozen when harvesting occurs. Also remedial measures should be taken. For example, a dozer or simply a log dragged behind a skidder or tractor can be used to help level ruts. Although rutting should be avoided, where they do occur, operators should be required to back-blade and fill depressions to their proper grade. Major wet ruts should not be graded until the ground dries out.

Soil and water runoff
Muddy water run-off from timber harvest roads, skid trails, and landings can pollute nearby water bodies and harm associated fish, wildlife and their habitat. The problem is compounded when vehicle fluids such as hydraulic fluid, oil, and gas enter adjacent watercourses. The key to protecting forest water quality is to minimize soil disturbance and water-crossings.

Soil erosion
Three major factors affect the susceptibility of a site to soil erosion:
- slope gradient
- length of site slopes, and
- soil texture (particle size).

Slope gradient of site surface
The susceptibility of a site to soil erosion increases sharply with slope angle. In general, long and/or steep slopes are more prone to erosion than short and/or gentle slopes. Slope zones should be delineated on topographical maps of the site and labelled. Three slope classes are

defined in **Table 8.3.1** for use in the site evaluation. Many ravine slopes are not accurately mapped on Ontario Base Maps (OMB) or topographical maps probably because they were not detected.

Slope gradients should be measured perpendicularly to the contours and computed as a percentage. The slope percentage (%) is the vertical distance divided by the horizontal distance (i.e., a 1:1 slope equals 100 % slope). Boundary determination of both regions of uniform and steep relief is not difficult. But delineation of areas with varying slopes may not be as simple. Sometimes it may be necessary to measure the gradient between individual contours to ensure adequate consideration of small-scale topographic variations.

Table 8.3.1: Slope gradient classes.

Slope %	Description
10	Gentle
10-15	Moderate
Over 15	Steep

Slope length

Longer slopes are generally more prone to erosion. Slope lengths can be determined by measuring the distance from crest to toe, perpendicularly to the contours. The total length of the slope should always be used even if part of it lies outside the site boundary. Moderate slopes are less than 70 m in length; long slopes exceed 70 m.

Soil texture

Soil texture also determines the potential for erosion. The relative proportions of sand, silt, and clay can be determined through field estimation, and used to classify the soil as either coarse textured (sandy), medium textured (loamy or silty), or fine textured (clayey). Normally, sandy and clayey soils tend to resist erosion better than loamy soils (**Table 8.3.2**).

Table 8.3.2: Susceptibility of various soil types to erosion.

Soil Type	Susceptibility to Erosion
Heavy Clay	Low
Clay	Low
Silt Clay	Medium
Sandy Clay	Low
Silty clay Loam	Medium
Clay Loam	Medium
Sandy Clay Loam	Medium
Silty Loam	High
Loam	High
Sandy Loam	Medium
Silt	High
Loamy Sand	Low
Sand	Variable

5. Disturbance to wildlife

It is important to consider the needs of wildlife because many species help to keep the forest healthy, perform valuable ecological services, are barometers of environmental health, and provide opportunities for hunting, wildlife viewing, and nature appreciation. In addition, some species merit special consideration because they are rare or declining in numbers due mainly to human activities.

Unfortunately, timber harvesting disturbs many species of wildlife, particularly when it is conducted during the breeding season of animals living within and/or using the forest and adjacent habitats. Even during the winter months, it can stress wildlife such as squirrels and deer by disrupting shelter habitat. Forest managers should know how timber harvesting affects wildlife species to ensure they are disturbed as little as possible.

How wildlife are affected

During timber harvest, noise, road construction, the felling of trees, and skidding of logs all unduly disturb wildlife. However some disturbance is short-term.

Road construction
Road construction for timber harvest may result in the fragmentation of forest habitat (Woodley and Forbes 1997). These roads also permit easier access to many forests, encouraging the introduction of invasive exotic species (e.g., from seeds transported by vehicles tires), and a reduction in local flora and fauna due to increased human presence and associated disturbance.

Felling
Tree felling affects the remaining stand structure and composition, as well as the amount and distribution of important wildlife habitats such as stick nests, foraging areas (e.g., mast-producing trees and shrubs), cavity trees, down woody debris, seepage areas, and conifer cover. Managers and tree-markers must recognize these features (**Table 4.4.1**) and then designate appropriate buffer zones to protect them during felling activities. Some species of wildlife may increase in stands after harvesting due to habitat changes (e.g., harvesting increases food supply).

Skidding
Large woody debris such as logs, branches, and stumps comprise a major component of hardwood forest and supply critical wildlife habitat. Approximately 15 % of the wildlife in central Ontario uses this debris (Naylor 1998). Therefore it is preferable to leave cull logs in the stand where they can provide habitat and return nutrients to the ecosystem. In addition, skidders should not crush larger logs and rotting stumps, allowing them to decompose naturally.

Machine noise
Noisy machines can force wildlife from their nests (e.g., raptors, herons, songbirds), dens, or burrows (e.g., foxes, coyotes). Consequently it is better to avoid operating machinery near

breeding and nesting sites from March to the end of July. At all other times, to reduce noise, shut down idling equipment, reduce truck speeds to and from the landing, and use equipment with noise-reducing features.

6. Other site impacts

There are other site impacts that may need to be considered or dealt with as they arise.

- On private land, damage to boundary fences may need to be repaired or tops felled onto adjacent property may need to be removed.
- Repairs or clearing of trails may need to be made to restore them to a suitable state for previous uses (e.g., hiking or snowmobile trails).
- Landings and trails utilized on adjacent properties may need to be restored to a state acceptable to the landowner.

Best management practices

To minimize harvesting damage, pre-harvest planning considerations should include:

- developing a pretreatment silvicultural prescription
- marking timber to be harvested
- marking and delineating sensitive environmental areas
- marking property boundaries
- selecting an environmentally sensitive harvest contractor, including meeting with a contractor on the site to review harvest operations
- negotiating a timber contract with logging damage and site and habitat protection clauses
- laying out forest access roads, skid trails, and landings
- harvest scheduling.

On the site, the impact of cutting and timber removal can be minimized by:

- good felling practices that also include the responsible management of debris
- careful skidding, and
- rehabilitating skidding trails, roads, and landings after harvesting.

Taken together these points comprise ‘best management practices’ that, if adhered to, will minimize harvesting damage to the site and forest stand. Each of these points is discussed below. The landowner/forest manager is responsible for ensuring that best management practices are followed, and must therefore monitor the harvesting operation daily. Harvesting standards to help monitor the harvesting operations are given in **Table 8.3.4**.

1. Developing a pretreatment silvicultural prescription

The pretreatment silvicultural prescription will represent the best silvicultural compromise among: landowner objectives; site potential and sensitivity; current stand structure, composition, and condition; and the protection of wildlife habitat and other natural heritage features (as discussed in the appropriate silvicultural guidelines subsection for the applicable forest cover type). It must be based on an accurate inventory (**Appendix C**).

2. Marking timber to be harvested

Selecting a tree-marker

Prior to harvesting timber, trees should be marked by a qualified tree-marker, preferably one that has been certified with the Ontario Ministry of Natural Resources Tree-Marker Training course.

Responsibilities of tree-markers

Qualified tree-markers should be aware of wildlife habitat features and other forest ecosystem values, as well as local biodiversity issues, potentially hazardous situations, and landowner objectives. Then they can use this knowledge to:

- Mark only the trees that can be felled without causing excessive damage to the residual stand. This may require that some markers learn about tree-felling techniques and potential hazards that could result from cutting of specific trees. Occasional damage to the residual stand is inevitable (e.g., a very large tree poses a hazard, is diseased, or is inhibiting the growth of three or more trees).
- Mark with a slash, cull, or undersized trees as targets for directional felling.
- Mark bumper trees (i.e., used to 'bump' the skidder load around turns in skid trails), using unique colors or paint with unusual symbols (to be removed at the end of the operation).
- Maintain significant wildlife habitat by trying to retain within each stand, some valuable trees (e.g., supercanopy, important mast-producers, cavity, nest, and denning trees), riparian and seepage areas, and existing wildlife travel routes (e.g., game trails).
- Mark trees located in the vicinity of skid trails within 2.3 m of the trail center line (Nyland 1994). If the marking operation occurs after roads and landings have been constructed, the marker must assess construction impacts on individual trees (OMNR 2000).
- Make the best silvicultural decisions in terms of stocking, quality, and species selection.
- Alter skid trail location if necessary.
- Protect the health and safety of forest workers by clearly identifying potential hazards that are to be left in the stand, or not readily visible to workers (e.g., dangerous trees and limbs, bees and wasp nests) and leaving unmarked, trees that cannot be felled safely (e.g., trees on cliff faces or near power transmission lines). The mandatory application of red paint is suggested for denoting a reserve around hazardous snags to be left for their wildlife habitat value (OMNR 2000).
- Realize that markers cannot locate or identify every hazardous situation.
- Seek the advice and opinions of professionals when unsure about conservation status of species within a stand and about how to best maintain natural heritage features.

How trees are marked

It is suggested that OMNR tree marking standards are followed on private land to help ensure more consistent application of prescribed silvicultural activities. The paint color should be stipulated in the marking prescription. Trees to be harvested are usually marked with yellow or orange paint. Generally, red paint is used to mark stand and reserve boundary lines; blue paint is used to mark trees to be retained (e.g., crop or wildlife trees); black or gray (depending on tree bark color) paint is used to erase marking errors.

Trees are marked at eye level, and at the butt with a slash in a seam or depression. Often trees are marked with three dots spaced equally around the tree so that the tree-markers, landowner, and logger can see which trees have been marked from any direction in the woodlot. The butt mark should be made at or very close to the ground. It should always be on one side of the tree (e.g., south side). This makes it easier during the harvest to check whether the logger is cutting only marked trees, especially where there is deep snow or ice. Loggers can cut the stump within 5 cm of the ground.

3. Marking and delineating sensitive environmental areas

Why are they important?

Sensitive environmental areas in forests are places where no harvesting should occur because of the sensitivity of these areas to harvest activities, and their high value to the forest ecosystem, associated wildlife, and human users. These include riparian zones and seepage ways; steep or unstable slopes; wet depressions; significant wildlife habitat features and areas such as patches of conifers; and forest communities supporting populations of rare, uncommon, or declining species (VTE species). Other examples include large individual trees, leaning trees, and trees susceptible to windthrow found growing along a creek whose stumps should be retained in the embankment to prevent soil erosion. These features and areas are summarized in **Table 4.4.1**.

How to mark them

Outside and adjacent to streamside buffers, mark for no more than one-third reduction in basal area, assuming a 20-year cutting cycle, in normal operating areas.

- To avoid possible damage by machinery, avoid marking trees near rare plants, seeps, and other wet areas. Since the time of year affects how well these can be seen, make sure they are identified and their locations are well marked during the summer months, prior to harvest.
- Tree-markers in southern Ontario are encouraged to update their plant identification skills.
- Recognize, mark, and delineate special situations that require buffers from harvest activity, e.g., moose calving sites, animal dens, wildlife corridors, stick nests, snags, and human recreation routes (**Table 4.4.1**).
- Depending on the situation, to avoid damage, either retain trees that lean excessively into an area of concern or carefully fell them.
- Clearly mark a no-cut zone of 5 m around all waterbodies and along all watercourses to ensure the growth and/or protection of mature trees immediately adjacent to the stream, riverbank, or lake. Such marking can help to provide a natural input over time of some woody debris into the aquatic system that can serve as valuable habitat for fish (Woodley and Forbes 1997).

4. Selecting a contractor

Before accepting any offers from contractors it is advisable to:

- Visit properties that contractors have recently harvested and discuss their performance with the landowners.

- Ask loggers about their experience, harvest methods and environmental ethic.
- Ask them about their equipment to ensure that it is suitable for the job. For example, contractors should use appropriate skidders or tractors, and landowners should prevent them from bringing oversized machines onto the job. Large machinery requires wide trails and more room to turn, leading to an increase in the incidence of stem wounding. Larger, heavier machines also cause more soil rutting and compaction that can damage and expose tree roots. In many stands, the use of a loader can reduce the area required for a log landing.
- Only interview those who consider forest ecosystem protection to be a priority.
- Consider contractors who have access to diverse markets for sale of the wood. A market for small diameter wood (i.e., fuelwood) is particularly important because it encourages contractors to harvest the small stems rather than leaving them standing, and therefore meet the target diameter distribution specified in the silvicultural prescription. It also reduces the necessity of planning for two separate entries into the property by two different operators looking for different products. Frequently, the price contractors are willingly to pay for the timber will reflect whether or not they have access to diverse markets.
- Realize that many sawlog operators are not interested in buying firewood and they use over-sized equipment to get it, resulting in more damage to the site.
- Ensure that the hired contractor is familiar with local tree bylaws (**Box 8.3.1**) and agrees to respect them.
- Work only with contractors who have both Workplace Safety Insurance and General Liability Insurance, and whose operators are certified.

Prior to commencement of the harvest, meet with the contractor on the site to discuss all aspects of the operation and clarify all potential misunderstandings.

Box 8.3.1: Tree bylaws

Many municipalities in southern Ontario have adopted tree bylaws to protect the woodlots within their jurisdiction. These bylaws stipulate that harvesting be in accordance with good forestry practices (e.g., as outlined in **Section 2** of this guide). For example, trees must be marked by a qualified (by OMNR) tree-marker, or silvicultural prescriptions must be based on silvicultural guidelines issued by the OMNR. Many advocate seeking the advice of a professional forest manager. Some of them have regulations on excessive damage. Notice of Intent forms may need to be submitted to the municipality prior to harvest. Possible infraction charges could include a replanting order, fines, or imprisonment. Contact the municipality in which the forest is found to determine whether a tree bylaw exists, and if so, ask for a copy of it.

5. Negotiating a timber sales agreement

The timber sales agreement is a signed contract between the landowner and the harvesting contractor that stipulates conditions of the harvest and the selling price of the wood. Listed below are important considerations that should be part of any such contract. See the Extension

Note *Selling Standing Timber* for a guide to preparing a contract. Many landowners stand to benefit from consultation with a professional forester, forest technician, or forestry consultant to assist them with managing and supervising the timber sale, and may wish to speak to a lawyer about contracts or timber sales agreements.

- Include in the contract, specification on construction of landings, roads, and skid trails as well as their cleanup, by referring to these best management practices (Jones 1993).
- Include a clause that clearly identifies designated skid trails and prohibits development of any additional trails that have not been approved (Nyland 1994).
- Limit the number of pieces a contractor can skid at one time, to improve tracking and reduce bumping of trailside trees (Nyland 1994). Also set a maximum length (8 m or 25 ft.), and insist that tops and branches are removed at the stump.
- Add to this contract, provisions about skidding (Nyland 1994). Provisions may include keeping the skidder on skid trail and using the mainline to winch trees out to the skidder. This technique is useful for winching trees from a moist site or for protecting advanced regeneration while skidding.
- Include an underlined clause that clearly specifies a significant penalty for damaging or cutting unmarked trees.
- Take time to discuss the use of directional felling and other work practices to reduce skidding damage (Nyland 1994).
- After an appropriate time, revisit the harvested stand to assure that all rehabilitation measures are effective. Maintain water-control devices and road surfaces as necessary (Jones 1993).
- Where possible, close roads into the stand after the harvest.
- When potential buyers are shown or negotiate a sale, have a prospectus outlining the conditions of the timber sale available so that all costs can be estimated and factored into the stumpage price (Jones 1993).
- Include a clause that states that all harvesting equipment should be power-washed (e.g., using a compressor) prior to transporting it from one site to the next to avoid the transfer of undesirable plant species, diseases, or insects.
- Include within the contract, a clause giving the landowner the right to stop all forest activities if conditions within the contract are broken. See the Extension Note *Selling Standing Timber*.
- Prior to harvest, landowners might consider taking some photographs of sugar shacks, stream crossings, bridges, rail fences, or other sensitive areas.
- In small or medium-sized woodlots, landowners could butt mark high value stems that are being left as part of the residual stand with a paint of a different color than that used to mark trees for harvest. Then these trees could be counted by species, and shown to the contractor.

6. Forest access roads, skid trails, stream crossings, and landings

Forest access roads, skid trails, and landings are necessary for the safe, efficient, and economical extraction of forest products from a stand. Access roads link the forest to a public road. Specifications for their construction vary, depending on the amount of wood to be harvested, the number of years the road will be used, and the season(s) of harvest. Skid trails are for temporary use during the timber harvest and are used to skid the trees to the landing areas. Landings are small clearings located along the forest access roads or in open fields beyond the woodlot and connected to skid trails. Here felled trees are cut into logs and piled in different product assortments prior to loading onto trucks for transport to mills.

The detrimental impacts of access roads, skid trails, and landings on the forest ecosystem can be minimized through the application of proper layout and construction methods. Wherever possible, skid trails and roads should avoid steep slopes (e.g., greater than 10 % for roads; greater than 15 % for skid trails), wet spots, seepage and poorly-drained areas, and intermittent streams. Also landings should be located outside of stands to be harvested, especially in small woodlots. Landowners should consider sharing a landing, site access, and skid trails to reduce harvest disturbances.

Forest access roads

Roads create the most lasting disturbance on logged areas and therefore should be considered as a permanent investment on forested land. Careful planning and road layout will help to mitigate potential problems. A well-planned and constructed road system will meet user needs without seriously harming other resources (Kochenderfer and Helvey 1989).

- Local topography, adjacent land ownership, and the biological character of the forest to be harvested, as well as the type of silvicultural systems and equipment to be used, will determine the location and spacing of access routes.
- Following a thorough on-the-ground examination of the forest stand and surrounding area, outline the access road location on aerial photographs and topographical maps.
- Locate and mark control points such as landings, rock outcrops, and areas to avoid such as significant wildlife habitats.
- Think about placement of skid trails and landings to help determine the most suitable location for an access road.
- Ensure that the chosen access route will minimize negative impacts on the site, as well as on known and potentially sensitive features of the stand.
- Ensure that the final road location is well marked and will provide access to the entire tract.
- Ensure that a system of landings and skid trails can be tied into the proposed access road.
- Fell trees within forest access roads and skid trails (as opposed to bulldozing them over).
- When practical, construct access roads in dry weather, ensuring proper placement of culverts and ditches for drainage.
- If the road is to be used for more than one year or during wet seasons, it may be necessary to apply gravel to the road surface.

Skid trails

Before harvesting, plan a tentative layout of all skid trails and clearly specify how they should be constructed. The input of timber harvest operators might be helpful.

- Refine the trail layout on the site either during the tree marking process or after it. Often trails will be made where trees are removed.
- A trail system that covers no more than 10 to 15 % of the area is a reasonable objective. This can be achieved by spacing trails at least 60 m apart. This layout will allow a contractor to winch out most of the logs without backing too far off the trail and will

considerably reduce damage to soil and vegetation caused by the tires of the machine. Remember that increasing the amount of trails often decreases the amount of productive forest.

- Use straight and gently curving skid trails and follow the contours of the land wherever possible.
- To help protect the site and maintain the aesthetic value of it, wherever possible, avoid using the primary footpath and main entrance to the stand.
- Keep trails outside the forest as much as possible.
- Avoid creating openings on the windward side of the forest to maintain cover that can reduce the incidence of windthrown trees.
- Control and minimize site-damaging effects to soil stability and water quality, such as rutting, accumulation of water, and soil compaction from harvest equipment by avoiding sensitive areas such as watercourses, seasonal ponds, seeps, steep grades (e.g., greater than a 15 % slope), and poorly-drained areas.

Stream crossings

Stream crossings are one of the most important features of the road system. Their improper planning or construction can result in soil erosion and introduction of sediment into a stream or other water body that might seriously harm water quality and aquatic life and habitat. According to Section 35 (2) of the Fisheries Act, a permit may be required for the construction of stream crossings. The Department of Fisheries and Oceans or the local area Conservation Authority can assist with the interpretation of this requirement and can describe permits that may be required.

- Whenever possible, do not cross streams with skid trails. Where this is unavoidable, use temporary bridges or spans rather than temporary culverts (Georgia Forestry Commission 1999). However temporary culverts are better than using nothing at all. The temporary bridge should be removed and the stream should be restored (i.e., remove fill materials, replant with native vegetation) after the skidding has been completed.
- Cross streams at right angles.
- Try to use a single crossing.
- Protect water quality by keeping the stream bank intact, minimizing the amount of fill dirt entering the stream, and (ideally) by using water-permeable fill materials that are easy to recover in the restoration process (Georgia Forestry Commission 1999).
- When possible, plan to log when the ground is frozen or at least dry. Reinforce sections of soft ground by placing unmerchantable logs perpendicular to roadways. Provide additional protection by placing slash in skid trails when it will not interfere with other activities, for example the subsequent fuelwood operation.

Landings

Equipment concentration and vehicle traffic in log landings results in a high degree of soil disturbance, soil compaction, and rutting. Storm water runoff and surface erosion may increase on these exposed areas and could adversely affect water quality. Planning landing locations before harvest begins reduces damage to the site and the stand (Nyland 1994).

- Whenever possible, place landings outside the woodlot (e.g., in an adjacent open field) because the disturbance they cause is long-lasting.

- Locate landings in well-drained areas away from water bodies (e.g., streams, ponds).
- Organize landings to accommodate sorting, processing, and short-term storage and to allow safe movement of workers and equipment (Jones 1993).
- Depending on the location of main roads, create landings that permit log trucks to get as close as possible to the woodlot; damage to site and wood, as well as costs are reduced if skidding distances are minimized.
- Minimize the amount of wood waste (e.g., bark, branches, blocks, and other debris) on the landings through good utilization of it and by cutting and leaving unmarketable trees or pieces of trees in the woods (Jones 1993). Do not bring unmarketable material to the landing only to abandon it.
- When creating landings, it is preferable not to bulldoze the area but rather cut the woody vegetation to ground level so it can regenerate after the harvest and provide habitat.
- The spacing of landings depends on local topography, stand conditions, other resource constraints, and skidding distances. Landings should be located so that the longest skidding distance is less than 370 to 460 m. According to Nyland (1994), average skid distances of 250 m are appropriate. However, for harvesting of woodlots in southwestern Ontario, the average skidding distance is closer to 350 m and occasionally can reach 1 km (P. Robertson, Trees Unlimited, personal communication,1999).
- In southwestern Ontario there is usually just one landing for each woodlot being harvested, and never more than two of them (P. Robertson, Trees Unlimited, personal communication, 1999).
- In agricultural areas of southern Ontario, landings are often located on adjacent agricultural land. Consequently, timing of logging may need to coincide with dates when crops are not present in the fields and agreement might have to be reached about compensation for lost crops within the landing area.
- The most practical landing location is sometimes on an adjacent property, necessitating negotiation of an agreement with the adjacent landowner for use of his property.
- The size of landings depends on whether the logs are stacked or not. Landings with stacked logs are preferable and will not exceed 0.2 ha; landings can exceed 2 ha in area when logs are unstacked or left in tree lengths (P. Robertson, Trees Unlimited, personal communication, 1999).

7. Harvest scheduling

The timing of the harvest can significantly affect the degree of damage to residual trees and understory vegetation, soils, tree regeneration, and wildlife species, as outlined in the following and summarized in **Table 8.3.3**.

Damage to residual trees and understory vegetation

Walsh (1980) found that harvesting during the growing season caused twice as much damage as winter harvesting (i.e., the dormant season for trees). Also damage to understory vegetation, particularly herbaceous species, can be reduced by winter harvesting when snow is on the ground because the living parts are below the soil surface and protected from harvesting operations (Reader 1987). As a general rule, operators should strive for 0 % damage to residual trees. Some landowners might consider including a clause in their contract that specifies the levying of financial penalties for damage in excess of 10 %.

Some tips to minimize damage to residual trees and understory vegetation include:

- Avoid harvesting during spring sap flow and growth period from March to July when trees are more susceptible to stem abrasion and soils are more easily compacted.
- Try to log in winter, or at least from August through mid-September, especially if the woodlot supports significant wildlife habitats (e.g., rare plants, raptor nesting area, significant size of forest interior).
- Harvest during October and November is fine if weather during these months has not resulted in wet soils that are more susceptible to damage from harvesting activities.
- If the intention is to regenerate species requiring some ground disturbance (e.g., birch, cherry, beech, hemlock, pine), harvest when snow does not cover the ground.

Damage to soils

Some tips to minimize damage to soils include:

- Preferably harvest when the ground is frozen or dry.
- Avoid harvesting during wet weather, and in particular, during the spring break-up period (i.e., March to May) to minimize soil rutting, compaction, and erosion. These problems are difficult to fix.
- Do not skid during and immediately following a heavy rain.

Damage to wildlife species

Some tips to minimize damage to wildlife include:

- Avoid harvesting during breeding/nesting season, preferably from March 1 to August 1, especially if birds that are dependent on undisturbed forest interior habitat (e.g., hawks, songbirds) are known to use the woodlot.
- In general, silvicultural activities should be restricted within 200 m of active red-shouldered and cooper's hawk nests during the nesting season because these are both species of conservation concern and are sensitive to disturbance. Other species may require smaller buffers at this time of year and the advice of local OMNR ecologists or consultants should be sought prior to any harvest. At a bare minimum, nest trees for birds of prey should be identified, marked, retained, and protected from the felling of adjacent trees.
- Since local populations of some sensitive forest interior bird species can best be maintained by retaining larger blocks of forest cover (e.g., at least 4 ha), landowners of large forest tracts might consider not harvesting some large blocks at any time. Or as an alternative, large woodlots could be broken into 8-15 ha compartments that might be harvested sequentially, allowing 5 to 8 years recovery time between operations.

Due to the nature of harvest operations, both the landowner and the contractor need to be cooperative and flexible. Landowners should also trust the contractor but make sure that the latter does not intimidate them. For example, when it appears that there is insufficient time left remaining in the winter season or the ground is not frozen, landowners should refuse to start a harvest, or shut down operations that are causing damage, despite pressure to get the job done.

Table 8.3.3: Conditions that influence decisions regarding when to harvest.

Season	Harvesting at this time:		
	Advantages	**Disadvantages**	**Prohibitive Conditions**
Spring-Mar.-June	• Good visibility during early spring prior to leaf out	• Tree bark is soft and easily damaged • Ground is thawing and is more susceptible to rutting • Migratory birds are beginning to establish nesting territories and may be disturbed	• Very moist to wet sites
Summer June-Sept.	• Ground is dry • Precipitation is minimal	• Regeneration is in full leaf and vision is restricted • Regeneration is more susceptible to damage • Some birds have not fully fledged • Crowns are in full leaf and may cause more damage to branches of adjacent trees during felling	
Fall-Sept.-Nov.	• After leaf fall vision is greatly improved • Breeding birds have fledged • Plants are going into dormancy	• Precipitation usually increases and ground retains more moisture	• Very moist to wet sites
Winter-Dec.-Mar.	• Ground is frozen therefore minimizing rutting on soft sites • Good visibility in heavy regeneration • Damage to regeneration is minimized	• Accumulation of snow makes felling more difficult and can lead to high stumps • Skid trails can thaw and become susceptible to rutting	• Steep slopes

8. Felling practices

The following steps should be considered to help to protect the cutter, optimize felling production, and clean up woody debris.

Worker safety

- Managers should ensure use of all pertinent safety gear (e.g., safety glasses; hard hats; ear protection; face shield; chainsaw gloves, pants and boots).
- Fell hazardous trees first (*Occupational Health and Safety Act* (*OH&SA*) RSO 1990) but leave snags standing so long as they appear to be wind firm (Anderson and Rice 1993) and are outside the operating area (e.g., at least one tree length from marked trees).
- When it appears to be too dangerous to work under a hazardous tree, the hazard tree must be cut first (Section 109, *OH&SA,* R.S.O. 1990) or trees in the vicinity of the hazard tree should not be cut.
- Trees that are hung-up need to be "felled forth by winching or pulling using a cable or chain from a safe distance or by other safe means" (Section 110, *OH&SA*, R.S.O. 1990).
- Maintain safe equipment, sharpening saws frequently and safely storing oils and fuels; do not litter by discarding chain saw oil containers, pop cans, cigarette packages, coffee cups, lunch bags.
- Do not fell trees in moderate to high wind conditions as the risk of losing control and affecting personal safety are too great.
- When monitoring a harvest operation, the landowner/forest manager should always wear a hard hat, safety boots and highly visible clothing when in the woodlot. This person should also wait for the skidder operator to come out to the landing and they should walk in with the skidder. The skidder will safely lead the person to the cutting area and make the cutter aware there is a third person in the woodlot (P. Robertson, Trees Unlimited, personal communication 1999). The cutter should be notified when the inspector is leaving the stand.
- When following the skidder maintain a safe walking distance from the machine.

Public relations

- The landowner/forest manager should notify adjacent landowners that a harvest operation is taking place and explain the dangers and safety precautions and answer their questions.
- The property of adjacent landowners must be respected. For example, trees that have been felled across a property boundary line must be winched back across the boundary. In addition, it is preferable not to harvest too close to the property boundary, and try to blend trail systems and share landings.
- If the property has significant features, notify the local OMNR office and Conservation Authority.
- Notify tenant farmers where applicable.
- Notify the respective agencies if a pipeline or hydro line runs through or adjacent to the woodlot. Hydro One wants to inspect all cutting adjacent to their lines. They will fell any trees they feel are "risky", at no cost to the landowner.
- Consider asking the cutter while he is in the woodlot to prune some suckers, lower limbs, or cut undesirable vegetation such as invasive shrubs (e.g., buckthorns). Invasive shrubs may be marked with a slash during tree marking.

Optimize felling production

- Start cutting at the back of the stand to avoid piling up limbs and tops that become obstructions to the harvesting operation, and to allow for the use of marked, uncut trees as bumper trees.
- Use the surrounding site conditions to determine where to fell trees.
- Fell trees away from sensitive areas (e.g., streams, seeps, stick nests) and away from good quality residual trees.
- Utilize directional felling techniques (**Box 8.3.2**) to drop trees in open areas and avoid directly hitting other trees (Nyland 1994).
- When direct hits are unavoidable, aim for low quality, diseased trees first. In some cases, the tree-marker will specially mark cull trees with a slash to be used as aiming points (Nyland 1994).
- Try aligning the tree for straight winching or up to a 45° angle to the skid trail to make it easier for the skidder to pull the tree out.
- Skid trails must be kept clean of any tops. Do not permit the contractor to fell trees back into the trail. Tops that are on the trails should be cut apart; skidders should not be used to push them aside. This practice results in less scarring and makes it easier to process the tops for firewood.

Box 8.3.2: Directional felling

Directional felling is a skillful cutting technique used to control the direction in which a tree is felled. It helps the cutting crew to select where most damage will occur and provides safety to the logger. Directional felling also helps to position the downed tree for the skidder, so that damage to trees from skidding is minimized (Jones 1993, Anderson 1994*b*). It can also reduce the incidence of hung-up trees that cost time to pull down with the skidder.

A series of plastic wedges and proper cutting techniques are used to directionally fell trees. Courses on this practice are offered through the Apprenticeship and Client Services Branch office of the Ministry Training, Colleges and Universities through the Ontario Forestry Safe Workplace program.

Taking care of debris

- Limb and top harvested trees where they fall, keeping slash down to 0.6-1.2 m (2-4 ft.) above ground throughout the harvested area. This improves post-harvest aesthetics, facilitates future access, and minimizes the amount of wood waste on the landings.
- A large amount of waste wood from tree tops and hollow stems may be generated through a timber harvest. Often this material is used as fuelwood. If there is a firewood market for the tops, the tops might be cut to within one meter of the ground; if no market exists, the tops might be cut to be no higher than 80 cm above the ground (P. Robertson, Trees Unlimited, personal communication 1999).
- If tops or other woody debris are left in the woods, they can provide important wildlife habitat, a source of organic matter and nutrients for the soil, and a rooting medium for tree seedlings. See the Extension Note *Restoring Old Growth Features to Managed Forests in Southern Ontario*.
- Snags that must be felled should be left on site. These dead trees will provide a regular supply of woody debris to the forest floor and create habitat for more than 30 % of all terrestrial vertebrates in southern Ontario forests (Nyland 1994).

- When limbing trees at the stump, leave large, hollow or unmerchantable logs in the forest for wildlife rather than cutting them as blocks at the landing. Logs that are most effective for wildlife are longer than 2 m and 60 cm in diameter.
- Cut stumps of leaners and damaged trees in the understory low to the ground (Jones 1993). This encourages sprouting on some species like red oak and basswood, helping to regenerate the forest (Georgia Forestry Commission 1999; Jones 1993).
- In regions where deer browsing severely disrupts natural regeneration, tops may be left uncut to protect new seedlings (Jones 1993).

9. Skidding practices

The use of bumper trees and a cable winch are skidding techniques that can help to minimize damage to the physical environment and residual stems. Logs to be skidded should normally not exceed 8 m (25 ft.) in length unless trail layout is suitable for longer lengths. All trees should have tops and branches removed at the stump prior to skidding.

Use bumper trees

- Start cutting at the back of the stand to allow for the use of marked, uncut trees as bumper trees.
- Locate bumper trees at key points along the skid trail to guide hauling equipment around curves and protect trees and seedlings to be left for later harvests (Van Ryn and Lassoi 1987). Bumpers can include trees of poor quality, small pole trees, uncut marked trees, and stumps cut high (Dey 1994 *in* Rice 1994). This concept is based on the idea that it is better to have lots of damage on one tree (i.e., the bumper tree) than some damage on many trees.
- Harvest bumper trees last, when the other wood has been hauled away (Van Ryn and Lassoi 1987).
- Designated bumper trees of fuelwood size could be left for the fuelwood contractor to cut if a subsequent fuelwood cut is planned.
- Boulders and hummocks can also serve as cushions between the logs and residual trees to be protected.
- Logging slash is a poor choice for use as a cushion because it is difficult and dangerous to clean up (B. Kropf and P. Robertson, Trees Unlimited, personal communication 1999).

Winching

- Operators should be requried to have 30 m of cable line.
- The cable winch on a skidder helps to reduce the amount of travel necessary by the skidder, thus helping to avoid damage to regenerating tree seedlings and the site (Georgia Forestry Commission 1999). Pulling a winch line 10-30 m is common and permits trail spacings of up to 60 m (Dey 1994).
- Avoid winching and skidding at sharp angles because they cause unnecessary de-barking of trees and put stress on equipment.
- If it is impractical to use the winch and backing to the vicinity of the felled tree is necessary, turning of the skidder should take place on the trail. Turning of the skidder in the area between identified skid trails should not be permitted.

Some useful skidding tips include:

- Use smaller hitches (i.e., number of logs) to improve tracking of logs behind the skidder and reduce damage to trees adjacent to the skid trail (Jones 1993). Skid tree length logs only when trails are straight.
- Reinforce sections of soft ground by placing logs or slash perpendicular to skid trail (Jones 1993).
- Avoid working two vehicles on the same trail. Inevitably they will get in each other's way and cause unnecessary damage as they go off the skid trails during passing.
- To select an entry point from a skid trail to hitch a log, the driver must enter the trail at angles of less than 45°, preferably where there are wide spaces between residual trees.
- Refrain from driving over large pieces of rotting debris to protect their ecological functions.
- Operators should walk rather than drive the skidder to find marked trees or locate access routes.
- Avoid driving the skidder through intermittent streams, seeps, vernal pools or other wet soils.
- Wash and service equipment away from any area that may create a water quality hazard, such as seasonal ponds or streams. Clean up and/or contain fuel and oil spills immediately. Safely dispose of oils, lubricants, their containers, and other wastes (Georgia Forestry Commission 1999).

10. Rehabilitating skidding trails, roads, and landings after harvesting

After harvesting is completed, work must be done to repair tire ruts and erosion problems along roads and skid trails, and treat compacted soils at the landing.

Roads

- When a road is abandoned, appropriate measures should be taken to prevent erosion and sedimentation of water bodies. This is necessary for maintenance of long-term site productivity and protection of aquatic ecosystems. This may include removal of culverts and bridges, grading slopes to stable angles, and planting native vegetation on areas of exposed mineral soil.
- Active and abandoned roads should be inspected annually and necessary repairs planned (Nyland 1994).
- Remove all temporary stream crossings and restore the streambed to its original elevation (OMNR 1997*b*).

Skid trails

- For areas with minor soil rutting, use cull logs and brush to disperse water while natural vegetation forms a protective cover. Vegetation will likely grow on these areas within one year following the harvest.
- Back-blade to fill in ruts and lower, high ridges.
- For major ruts, wait until the ground is dry to fill and grade; trying to level and fill under wet conditions will only aggravate the problem.

Landings

- Clean landings of logging debris, removing and properly disposing of all garbage, equipment parts, and other refuse.
- Level and smooth the ground and replant with appropriate native tree species of local origin (unless the landing is in a field or will be used again as a landing in 15-20 years). Or allow the landing to reseed itself. Do not replant with lawn mixes, or other non-native, biologically inappropriate seed/species.
- In landscapes with high forest cover (> 30 %), landings can serve as open areas that are attractive to many wildlife species (Jones 1993). Do not seed these areas with non-native legumes or grass species to minimize risk of introducing exotic invasive species. Instead scuff compacted soils on landings to encourage growth of native vegetation.
- In areas where native prairie vegetation once flourished, consider planting or seeding appropriate prairie species (see the Extension Note *Management Options for Abandoned Farm Fields*). In some areas (e.g., Norfolk County), prairie species may be present in the soil seed bank, and will regenerate on their own. Note that various wildlife organizations (e.g., National Turkey Federation, Ruffed Grouse Society) encourage landowners to plant forest roadways with non-native, often invasive seed mixes. This guide does not recommend introducing any non-native species into forests.
- Landings maintained as open areas can be re-used for subsequent harvests with minimal cost and effort (Jones 1993).

Harvesting standards

The following checklists can provide landowners and forest managers with a simple way of measuring the performance of harvest contractors. The quality of a job can be objectively determined by specifying standards in a timber contract that is negotiated prior to harvesting, and by sampling the forest stand during and after the harvesting operation. If possible, the harvesting operation should be monitored on a daily basis. Initiate remedial action immediately after discovery of a serious problem. If standards fall below those specified in the agreement, first discuss the situation with the contractor and try to work out the problems. If this is not possible, stronger methods may be employed, including financial penalties or legal action.

Assessing harvest damage

All forest operations must be monitored regularly, especially during critical periods such as road construction and rainy periods; during the layout of skid trails; and during harvest operations (Dey 1994). During this monitoring, the landowner or forest manager should communicate regularly with the contractor to discuss concerns and correct problems immediately. The landowner or forest manager might also conduct prism sweeps to audit the post-sawlog harvest basal area (and compare it with that specified in the tree marking prescription) and look at the stumps to record the age and growth rates of the harvested trees (P. Robertson, Trees Unlimited, personal communication 1999).

Acceptable minimum standards to consider and strive to attain during harvest operations include:

- 85 % of the residual basal area (of stems 10 cm and greater in DBH) must be free of major damage (OMNR 1998*a*)
- 90 % of the residual acceptable growing stock (AGS) must be free of major damage (OMNR 1998*a*), and
- no more than 10-15% of the site should be disturbed by harvesting (Nyland and Gabriel 1977).

In managed woodlots in southern Ontario, good operators can complete harvesting operations without causing logging damage, especially to residual trees in the stand. In areas where site conditions make damage-free harvests more difficult, a few minor scuffs on trees or the occasional broken sapling might be acceptable. In general however, landowners and managers should have "zero tolerance" for unnecessary logging damage. This is more likely to occur when landowners or managers regularly monitor the harvest operation, and have clear communications with the contractor. These people should be ready to speak with the contractor at the first sign of any damage.

A simple checklist that landowners and forest managers can use to inspect the harvest operation (adapted from Nyland 1994) is given in **Table 8.3.4**. *The logging damage audit tally sheet* provides landowners, consultants, auditors, and other field operations managers with an organized tool to tally tree damage (e.g., number of damaged trees) if there is a perceived problem. It also provides a summary and description of damage found during an audit. Flagging tape can be used in the field to identify the problem trees or areas. Completion of this tally sheet better enables landowners and managers to address any damage with the contractor.

First, the auditor should walk through most of the cutover area and determine whether there appears to be any logging damage problems. If there appears to be no damage, or only one or two minor occurrences, then there is no need to collect any data in order to quantify this low level of damage (i.e., close to 0 %).

However, if there appears to be more serious damage, the auditor should check the appropriate boxes on the tally sheet that correspond to the type and level of observed damage. Suspected tree bylaw infractions and other potential legal problems are best investigated by a qualified forestry expert using a detailed random sampling methodology.

Harvest contractors, and in the event of a legal dispute, lawyers and judges, need to know the acceptable limits of harvest damage. In other words, when is logging damage to trees considered to be unacceptable, and beyond normal logging damage? Listed below are examples of unacceptable damage that would have to be paid for by the contractor.

For trees greater than 10 cm DBH:

1. Damaged trees that are determined to be dead or have no future (e.g., trees with broken stems, uprooted trees, girdled trees through serious bark abrasion).
2. Trees that have been lowered in grade (e.g., trees that have had large amounts of their bark removed).
3. Trees that have wounds larger than 200 cm^2, or 30 cm in length, or more than one-third of the circumference of the tree, especially if these wounds are in contact with the ground.
4. Trees where logging damage has broken off branches greater than 7.5 cm in diameter at the base.
5. Trees pushed to a lean of 10^o or more.
6. Trees that have had more than 33 % of the crown removed.
7. Trees that have had more than 25 % of the root area damaged or severed.

For trees less than 10 cm DBH:

Damage to these smaller trees could be calculated using a ratio of damaged saplings equal to one tree larger than 10 cm DBH.

Conclusions

Careful harvesting does not require the expenditure of a lot of additional time or money. Over the long-term, it may even save or make money for the landowner and forest workers (e.g., lower costs of equipment maintenance, higher value of residual trees, additional contracts from other landowners). However, it does require a clear understanding of the principles and techniques outlined in this subsection and their correct application. Many of the practices that have been discussed in this subsection will lead to more productive operations. A good working relationship with timber harvest workers during road construction and harvest will facilitate successful implementation of forest management plans, stand prescriptions, and timber harvest agreements.

Table 8.3.4: Logging damage audit tally sheet.

Date: ______________________ **Auditor:** __________________________
Logger: ______________________ **Property:** __________________________
Stand: ______________________

Method

Using this table, record the number of trees showing the type of damage listed below. Trees may exhibit more than one type of damage. Preferably, walk all of the stand in which harvesting has occurred. Also examine trees along skid trails and access roads that extend outside the harvest area. If an unacceptable level of damage is found, stop the harvest and attempt to resolve the problem with the contractor.

Damage to trees larger than 10 cm DBH		
Type of damage	**How to identify/level of unacceptable damage**	**Number of occurrences/trees with damage**
Stem broken	Primary stem (or any other major limb) is broken	
Uprooted trees	More than one-half of tree roots broken and/or exposed	
Girdled trees	Area where bark has been removed encircles tree or is at least 50 % of the circumference of the tree	
Stem wounds	Gouging, scraping and peeling of the bark. This can occur at the ground level due to skidding or higher in the tree as a result of felling impacts Wounds are larger than 200 cm^2**,** or 30 cm in length, or more than one-third of the circumference of the tree	
Broken branches	Broken branches are greater than 7.5 cm at their base	
Leaning tree	Tree is leaning 10 degrees or more because of logging damage	
Crown damage	More than 33 % of the crown has been removed or severely damaged (broken branches comprise most of the damaged area)	
Root damage	More than 25 % of the root area is exposed or severed	

Table 8.3.4 *continued*

Damage to regenerating seedlings and saplings less than 10 cm DBH		
Type of damage	**How to identify/level of unacceptable damage**	**Number of occurrences/trees with damage**
Stem broken or tree bent over	30 % of the seedlings within the harvest area are broken	
Site damage		
Type of damage	**How to identify/level of unacceptable damage**	**Number of occurrences**
Tire ruts, skidding ruts	No ruts should be deeper than 15 cm (6 in.) on spur trails No ruts should be deeper than 30 cm (12 in.) on main trails	
Excessive number of skid trails	Skid trails are less than 60 m apart No primary skid trails closer than 60 m (200 ft.)	
Logging debris	No tops blocking the trail No debris leaning against any trees No limbs or tree tops left higher than 1 m above the ground No logs that have slipped out of the choker and are lying on the trail	
Excessive skid trail width	No skid trail wider than 3 m (10 ft.)	

8.4 OTHER CONSIDERATIONS APPLICABLE TO SOUTHERN ONTARIO

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by David Bland

The implementation of silvicultural prescriptions must always consider the setting in which they will be applied. The forested lands of southern Ontario are unique in several ways as discussed in the following.

Milder climate

Southern Ontario has a milder climate than the rest of the province, experiencing shorter winters with more fluctuation in air temperatures that can cause intermittent thawing of the ground surface and upper soil horizons. Therefore the timing of harvesting operations to minimize damage to soils and ground vegetation is more difficult, and local weather and site conditions must be carefully monitored. Forest managers must consider the climate of this part of the province as well as local weather conditions, when selecting and implementing their preferred silvicultural prescription(s).

Smaller, more visible forest stands

On average, the forest stands of southern Ontario are smaller than those of central and northern Ontario. At the same time population density is high in much of the southern region. As a result, many of the stands are more visible to the general public. Quite often these factors can affect how silvicultural prescriptions are implemented.

Visible damage resulting from sloppy harvest operations and harvest activities resulting in drastic and sudden changes in the appearance of a stand can generate negative public opinion, and may even discourage some landowners from practicing good forest stewardship (Jones 1993). This is especially likely where site or stand damage is highly visible, where forest areas are rendered inaccessible due to damaged access roads, or where public use of forest land is restricted due to hazardous conditions.

Also harvesting damage in small stands could cause greater negative impacts because it is likely to constitute a greater proportion of the overall stand. With fewer trees, especially mature seed-producing trees, the need to minimize damage to remaining trees is extremely important. Their small size and high visibility may also preclude the use of some prescriptions such as shelterwood and clearcutting, and some vegetation management techniques such as the use of herbicides and prescribed burning. Also smaller woodlots may be more susceptible to negative edge effects such as increased sunlight, desiccation, nest predation, and potential seeding-in of invasive species.

Greater biodiversity within forest stands

Forest stands in southern Ontario generally support a more diverse biota, especially herbaceous vegetation, than stands in other parts of the province. Knowledgeable residents of a municipality are likely to know the location of some of the more diverse stands and species of conservation concern. Some people are likely to protest if significant sites are threatened by harvest.

More species of conservation concern

Sometimes there are species present that should or must be protected (e.g., VTE species, declining species such as butternut, rare species). Silvicultural prescriptions must recognize them and preferably retain them or encourage their regeneration. Silvicultural activities that could result in their further decline or disappearance should be avoided whenever possible.

Greater problem with invasive exotics

Forest stands in southern Ontario face a greater threat from invasive exotic species (e.g., Norway maple, European buckthorn, gypsy moth, dogwood anthracnose) that undermine forest ecosystem integrity and may even diminish revenue from forest products such as veneer and maple syrup. Any management plan must ensure that planned silvicultural prescriptions do not encourage these species.

Greater problem with white-tailed deer browsing

Browsing by white-tailed deer can adversely affect the regeneration and growth of many species in woodlots of southern Ontario. In some areas, current deer populations and level of damage may even dictate to some extent, the available silvicultural prescriptions. Here, aggressive vegetation management may be required if certain management objectives are to be achieved, for example, the use of protective measures such as fencing, tree shelters, and/or underplanting to ensure regenerating tree seedlings survive. However, in areas with burgeoning deer populations, managers would be well advised to avoid the implementation of silvicultural prescriptions that might encourage browsing of the stand by these animals.

Greater desire for management for wildlife habitat as a primary objective

Many landowners in southern Ontario have other management objectives for their woodlots besides increasing revenue from forest products. Many of them will want to improve or even create wildlife habitat. Silvicultural prescriptions that protect or promote these habitats can be implemented but only in stands where their use is appropriate.

Greater desire to allow natural succession to occur

Other landowners may wish to only minimally manage their woodlots, preferring instead to allow natural succession to occur. Forest managers may be able to recommend to some of these people, a modification of single-tree selection that encourages the development of old growth (**Table 6.1.6**) as a feasible prescription. Such prescriptions should be considered for woodlots that are relatively healthy i.e., do not contain an understory of buckthorn.

Increasing public awareness of good vs. bad harvesting practices

Public awareness of what constitutes good and bad harvesting practices is growing rapidly and likely to continue to grow. Conscientious harvesting that protects the site and conserves associated wildlife will help to foster more positive public opinion of forestry operations in general and discourage sloppy, harmful operations. Furthermore, since most of the forested land in this part of the province is private, it is essential to use good harvest practices whenever possible. This not only provides opportunities for other landowners to learn about the best available ways to harvest trees, but also encourages these people to use them in their own woodlots.

Municipal zoning

The zoning of municipal lands in southern Ontario presents another important consideration for forest managers. Some stands have been designated as ANSIs by the OMNR because of their biological importance (e.g., old growth forest). Others may be located in environmentally sensitive areas (e.g., floodplain or bottomland forests). Managers and landowners must recognize these stands and their location. Often they are best left alone to provide other forest values to people and wildlife (e.g., protection of wildlife habitat or rare species, bank stabilization, prevention of erosion).

Some forest stands may not be located on lands zoned for specific protection but nevertheless merit special consideration. For example, stands that support locally uncommon tree species or trees of unusually large size might be managed using silvicultural prescriptions that recognize these unique attributes.

Woodlots within 5 km of the Great Lakes

Larger woodlots within 5 km of the Lake Ontario, Lake Erie, and Lake Huron can be especially important as resting, feeding, and staging areas for migratory birds and insects that must cross these large water bodies. Therefore harvest operations should not result in their degradation or disturb spring and fall migratory movements.

Greater need for restoration

Finally, the forests of southern Ontario present an interesting challenge. Due in part to past exploitation of forest resources; in part to increasing human population density in and around the remaining stands, as well as changing patterns of land use, forest cover and quality are somewhat impoverished, especially near urban areas. The restoration of these vestiges through the implementation of appropriate silvicultural prescriptions has the potential to ecologically improve the larger landscape. For example, prescriptions could be used to increase the existing forest cover in animal movement corridors linking isolated woodlots, hence improving natural seed dispersal and helping to offset population declines. Or they could create a broader range of forest types of different ages within a given region, thereby increasing biological diversity. Even relatively urban forests could benefit from some kind of restoration. Management plans could specify silvicultural prescriptions for the removal of exotic species and promotion of desirable regeneration.

Section 9
Literature Cited

Abrams, M. D. 1996. Distribution, historical development and ecophysiological attributes of oak species in the eastern United States. Annals of Scientific Forestry 53: 487-512.

Abrams, M. D. 1998. The red maple paradox. BioScience 48(5): 355-364.

Abrams, M. D. and D. A. Orwig. 1996. A 300-year history of disturbance and canopy recruitment for co-occurring white pine and hemlock on the Allegheny Plateau, USA. Journal of Ecology 84(3): 353-363.

Ahrens, W.H. 1994. Herbicide handbook of the Weed Science Society of America. Seventh ed. Weed Sci. Soc. Amer. Champaign Ill. 352 p.

Alex, J. F. 1992. Ontario weeds descriptions, illustrations and keys to their identification. Publication 505, Ontario Ministry of Agriculture and Food, Queen's Printer for Ontario. 304 p.

Alexander, L., B., C. Larson and D. P. Olson. 1985. The influence of wildlife on eastern white pine regeneration in mixed hardwood-conifer forests. Pages 40-45 *in* D. T. Funk (proc. compiler). Eastern white pine: Today and tomorrow: symposium proceedings, June 12-14, 1985, Durham New Hampshire. USDA Forestry Service, General Technical Report WO-51.

Anderson, H.W. 1973. Hardwood defects. Pages 37-58 (Appendix IV) in Management of Tolerant Hardwoods in Algonquin Provincial Park. Ontario Ministry of Natural Resources, Forest Management Branch. 84 p.

Anderson, H.W. 1985. Hard maple ring width study. Ontario Ministry of Natural Resources, Ont. Tree Improvement and Forest Biomass Institute, Maple. Unpublished Report. 20 p.

Anderson, H. W. 1994*a*. Hemlock: its ecology and management. Pages 61-86 *in* H.W. Anderson and A G. Gordon [eds.]. The tolerant conifers: Eastern hemlock and red spruce, their ecology and management.. Ontario Forest Research Information Paper No. 113, Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

Anderson, H. W. 1994*b*. Some implications of logging damage in the tolerant hardwood forests of Ontario. Pages 1-27 *in* J. A. Rice [ed.]. Logging Damage: The problems and practical solutions. Forest Research Information Paper No. 117. Ontario Ministry of Natural Resources, Queens Printer for Ontario.

Anderson, H. W., B. D. Batchelor, C. M. Corbett, A. S. Corlett, D. T. Deugo, C. F. Husk and W. R. Wilson. 1990. A silvicultural guide for the tolerant hardwood working group in Ontario. Ontario Ministry of Natural Resources, Queen's Printer for Ontario. 178 p.

Anderson, H. W. and J. A. Rice. 1993. A tree-marking guide for the tolerant hardwoods working group in Ontario. Ontario Ministry of Natural Resources Science & Technology Series, Volume 7. 227 p.

Anonymous. 1930. Form-class volume tables. Canadian Department of the Interior, Forest Service. 199 p.

Anonymous. 1948. Form-class volume tables. Canadian Department Mines and Resources, Dominion Forest Service. 261 p.

Arbogast, C. 1957. Marking guides for northern hardwoods under the selection system. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. Station Paper 56. 20 p.

Archibald, D. J., W. B. Wiltshire, D. M. Morris and B. D. Batchelor. 1997. Forest management guidelines for the protection of the physical environment, Version 1.0. Ontario Ministry of Natural Resources, Queen's Printer for Ontario. 42 p.

Arend, J. L. and H. F. Scholz. 1969. Oak forests of the Lake States and their management. Gen. Tech. Rep. NC-56. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Aucmoody, L. R., H. C. Smith and R. S. Walters. 1993. Acorn production in northern red oak stands in northwestern Pennsylvania. Gen. Tech. Rep. NE-680. USDA Forest Service, Northeastern Forest Experiment. Station, Radnor, Pennsylvania. 5 p.

Barnes, W. J., E. Dibble. 1988. The effects of beaver in riverbank forest succession. Canadian Journal of Botany 66(1): 40-44.

Basham, J.T. 1991. Stem decay in living trees in Ontario's forests: a users' compendium and guide. Information Report O-X-408. Forestry Canada, Ontario Region, Sault Ste Marie, ON. 69 pp.

Bates, P. C., C. R. Blinn, A. A. Alm and D. A. Perala. 1989. Aspen stand development following harvest in the lake states region. Northern Journal of Applied Forestry 6: 178-183.

Beck, D. E. 1990. *Liriodendron tulipifera* L. Yellow Poplar. Pages 406-416 *in* R. M. Burns and B. H. Honkala [tech. coords.]. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 877 p.

Belcher, D. M. 1992. TWIGS: The woodman's ideal growth projection system. Microcomputers, a new tool for foresters. Purdue University, West Lafayette, Indiana. 70 p.

Bell, F.W., D.G. Pitt, A.E. Morneault, and S.M. Pickering. 1999. Response of immature trembling aspen to season and height of cut. Northern Journal of Applied Forestry. 16(2): 108-114.

Bell, F. W., R. A. Lautenschlager, R. G. Wagner, D. G. Pitt, J. W. Hawkins and K. R. Ride. 1997. Motor manual, mechanical, and herbicide release affect early successional vegetation in northwestern Ontario. Forestry Chronicle 73: 61-68.

Bell, F. W., A. J. Willcocks and J. Kavanagh. 1990. Preliminary variable density yield tables for four Ontario conifers. Technical Report No. 50. Northwestern Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources, Thunder Bay, Ontario. 80 p.

Bella, I. E. 1986. Logging practices and subsequent development of aspen stands in east-central Saskatchewan. Forestry Chronicle 62: 81-83.

Bellhouse, T. J., B. J. Naylor and M. P. Twiss. 1993. Late winter habitat selection by moose in the northern Great Lakes-St. Lawrence Forest. Technical Report 25. Central Region Science and Technology Development Unit, Ontario Ministry of Natural Resources, Huntsville, Ontario. 17 p.

Berry, A. B. 1981. Metric form-class volume tables. National Forestry Institute Information Report PI-X-10. Canadian Department of the Environment, Canadian Forest Service, Petawawa, Ontario. 24 p.

Bey, C. F. 1964. Advance oak reproduction grows fast after clearcutting. Journal of Forestry 62: 339-40.

Boateng, J. O. and G. Ackerman. 1990. A guide to vegetation control equipment. British Columbia Ministry of Forests. Canada - British Columbia Partnership Agreement on Forest Resource Development: FRDA II, Victoria, B.C. 51 p.

Bowman, I. and J. Siderius. 1984. Management guidelines for the protection of heronries in Ontario. Ontario Ministry of Natural Resources, Wildlife Branch, Toronto. 44 p.

Boysen, E. 1994. Coppicing as a natural regeneration method in hardwoods: silver maple case study, Ontario Ministry of Natural Resources. Unpublished Report. 6 p.

Brissette, J. C. 1996. Effects of intensity and frequency of harvesting on abundance, stocking and composition of natural regeneration in the Acadian Forest of eastern North America. Silva Fennica 30: 301-314.

Brose, P. H. and D. H. Van Lear. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research 28: 331-339.

Brown, J. H., Cruickshank, V. B., W. P. Gould and T. P. Husband. 1988. Impact of gypsy moth defoliation in stands containing white pine. Northern Journal of Applied Forestry 5: 108-111.

Buchert, G. P, O. P. Rajora, J. V. Hood and B. P. Dancik. 1997. Effects of harvesting on genetic diversity in old growth eastern white pine in Ontario, Canada. Conservation Biology 11: 747-181.

Buckman, R.E. 1964. Effects of prescribed burning on hazel in Minnesota. Ecology 45: 626-629.

Buell, J. H. 1940. Effect of season of cutting on sprouting of dogwood. Journal of Forestry 38: 649-650.

Burgess, D., Baldock, J. A., L. S. Wetzel and D. G. Brand. 1995. Scarification, fertilization and herbicide treatment effects on planted conifers and soil fertility. Plant and Soil 168-169: 513-522.

Burns, R. M. and B. H. Honkala. [tech. coords.]. 1990*a*. Silvics of North America. 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington D.C. 675 p.

Burns, R. M. and B. H. Honkala. [tech. coords.]. 1990*b*. Silvics of North America. 2. Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington D.C. 877 p.

Canadian Forest Service. 1995. Silvicultural Terms in Canada. 2nd Edition. Policy, Economics and International Affairs Directorate. Natural Resources Canada, Canadian Forest Service. 109 p.

Canadian Forest Service. 1999. Forest health in Canada: An overview 1998. Natural Resources Canada, Canadian Forest Service. 60 p.

Canham C.D. and O.L. Loucks. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecology 65(3): 803-809.

Carlton, G. C. and F. A. Bazzaz. 1998. Regeneration of three sympatric birch species on experimental hurricane blowdown microsites. Ecological Monographs 68: 99-120.

Carmean, W.H. 1978. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. Research Paper NC-160. US Department of Agriculture, Forest Service, North Central Forest experiment Station. St. Paul, MN. 16 p.

Carmean, W.H., J. T. Hahn and R. D. Jacobs. 1989. Site index curves for forest tree species in the eastern United States. General Technical Report NC-128. USDA Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota. 142 p.

Chambers, B. A., B. J. Naylor, J. Nieppola, B. Merchant and P. Uhlig. 1997. Field guide to forest ecosystems of central Ontario. SCSS Field Guide FG-01. Ontario Ministry Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. 200 p.

Chapman, L. J. and D. F. Putnam. 1984. The physiography of southern Ontario, 3rd edition. Special Volume 2. Ontario Research Foundation, Ontario Geological Survey. 270 p.

Cherry, M. 1999. Genetic implications of climate change. Pages 23 –26 *in* Buse, L.J. and S.J. Colombo (eds.) The Impacts of Climate Change on Ontario's Forests. Ont. For. Res. Info. Paper No. 143.

Chimner, R. A. and J. B. Hart. 1996. Hydrology and microtopography affects on northern white cedar regeneration in Michigan's Upper Peninsula. Canadian Journal of Forest Research 26: 389-393.

Cho, D. S. and R. E. J. Boerner. 1995. Dendrochronological analysis of the canopy history of two Ohio old-growth forests. Vegetation 120(2): 173-183.

Clark, F. B. and R. F. Watt. 1971. Silviculture methods for regenerating oaks. Pages 37-43 *in* Proceedings of oak symposium, Morgantown, West Virginia, August 16-20, 1971. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania.

Clebsch, E. E. C. and R. T. Busing. 1989. Secondary succession, gap dynamics, and community structure in a southern Appalachian cove forest. Ecology 70(3): 728-735.

Cole, W. G. 1991. Prediction of tree growth and gap closure rates after selective cutting in second-growth northern hardwood forests. Ph.D. Thesis. University of Wisconsin, Madison, Wisconsin. 141 p.

Collins, S. L. 1990. Habitat relationships and survivorship of tree seedlings in hemlock-hardwood forest. Canadian Journal of Botany 68: 790-797.

Conway-Brown, M. 1984. Alternatives to herbicide in forestry. Pages 183-216 *in* Pesticide policy: the environmental perspective. Friends of the Earth Canada, Ottawa, Ontario. 230 p.

Cox, C. 1994. Pesticide users should follow the law! Journal of Pesticide Reform 14(1): 16-19.

Crow, T. R. 1992. Population dynamics and growth patterns for a cohort of northern red oak (*Quercus rubra*) seedlings. Oecologia 91: 192-200.

Dahir, S. E. and C. G. Lorimer. 1996. Variation in canopy gap formation among developmental stages of northern hardwood stands. Canadian Journal of Forest Research 26: 1875-1892.

Dale, M. E., H. C. Smith and J. N. Pearcy. 1995. Size of clearcut opening affects species composition, growth rate, and stand characteristics. Gen. Tech. Rep.. NE-698. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 21p.

Daniel, T. W., J. A. Helms and F. S. Baker. 1979. Principles of silviculture. McGraw-Hill, New York. 500 p.

Daughtrey, M. L., C. R. Hibben, K. O. Britton, M. T. Windham and S. C. Redlin. 1996. Dogwood anthracnose—understanding a disease new to North America. Plant Disease 80(4): 349-358.

Davidson, R. W., R. C, Atkins, R. D. Fry, G. D. Racey and D. H. Weingartner. 1988. A silvicultural guide for the poplar working group in Ontario. Ontario Ministry of Natural Resources, Queens Printer for Ontario. 67 p.

Davis, M. B. [ed.]. 1996. Eastern old-growth forests: Prospects for rediscovery and recovery. Island Press, Washington, D.C. 383 p.

Davis, M. B., T. E. Parshall and J. B. Ferrari. 1996. Landscape heterogeneity of hemlock-hardwood forest in northern Michigan. Pages 291-304 *in* M. B. Davis [ed.]. Eastern old-growth forests: Prospects for rediscovery and recovery. Island Press, Washington, D.C. 383 p.

De Franceschi, J. P. and F. W. Bell. 1990. Labour productivity and costs of motor-manual release of spruce from hardwoods in Manitoba. Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton, Alberta. Information Report NOR-X-312. 14 p.

DeGraaf, R. M., M. Yammasaki, W. B. Leak and J. W. Lanier. 1992. New England wildlife: Management of forested habitats. Technical Report NE-144. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 271 p.

Dey, D. C. 1994. Careful logging, partial cutting and the protection of terrestrial and aquatic habitats. Pages 53-69 *in* J. A. Rice [ed.]. Logging damage: The problems and practical solutions. Forest Research Information Paper No. 117, Ontario Ministry of Natural Resources, Queens Printer for Ontario.

Dey, D. C. 1995. Acorn production in red oak. Forest Research Information Paper No. 127. Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario. 22 p.

Dey, D.C. and M. Buchanan. 1995. Red oak acorn collection, nursery culture and direct seeding: a literature review. Forest Research Information Paper No. 122. OMNR. Ontario Forest Research Institute, Sault Ste. Marie, Ontario. 46 p.

Dey, D. C. and W. C. Parker. 1996. Regeneration of red oak (*Quercus rubra* L.) using shelterwood systems: Ecophysiology, silviculture and management recommendations. Forest Research Information Paper No. 126. Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste Marie, Ontario. 59 p.

Dillenburg, L.R., D.F. Whigham, A.H. Teramura, I.N. Forseth. 1993. Effects of below and aboveground competition from the vines *Lonicera japonica* and *Parthenocissus quinquefolia* on the growth of the tree host *Liquidambar styraciflua*. Oecoligia 93(1): 48-54.

Doepker, R. V. and J. J. Ozaga. 1991. Wildlife values of northern white cedar. Pages 15-34 *in* D. O. Langtane [ed.]. Northern white cedar in Michigan: Workshop proceedings, February 21-22, 1990, Sault Ste. Marie, Ontario. Agriculture Experiment Station Research Report 512. 122 p.

Dominy, S.W.J. 1987. Motorized brushcutting saws. Ontario Ministry of Natural Resources. Equipment Item Leaflet D.b.2. 5 p.

Dwyer, J. P., D. C. Dey and W. B. Kurtz. 1993. Profitability of precommercially thinning oak stump sprouts. Northern Journal of Applied Forestry 10(4): 179-183.

Ehrentraut, G. and K. Branter. 1990. Vegetation management by manual and mechanical means in Alberta boreal forests. Forestry Chronicle 66: 366-368.

Elliott, K.A. 1998. A short introduction to the forests of southern Ontario. Forestry Chronicle 74(6): 850-854.

Elliott, K.A., J. McCracken and A. Couturier. 2000. A management strategy for South Walsingham sand ridges/ Big Creek floodplain forest. Southcentral Sciences Section, Ontario Ministry of Natural Resources, Internal Report. 54 p.

Elliott, K.A., B.D. Batchelor, E.P. Boysen, A.S. Corlett, and S.R. Reid. 1997. Hardwood silviculture of the northeast United States—a field trip report. Southcentral Sciences Section, Ontario Ministry of Natural Resources. 21 p.

Environment Canada, Ontario Ministry of Natural Resources and Ontario Ministry of Environment and Energy. 1998. A framework for guiding habitat rehabilitation in Great Lakes areas of concern. 76 p.

Erdmann, G. G., T. R. Crow, R. M. Peterson, Jr. and C. D. Wilson. 1987. Managing black ash in the Lake States. General Technical Report NC-115. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 10 p.

Eyre, F. H. and W. M. Zillgitt. 1953. Partial cuttings in northern hardwoods of the Lake States – Twenty-year experimental results. Technical Bulletin No 1076. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 124 pp.

Falkenberg, N., D.R. Bazely and G. Mouland. 1999. Restoration of Red Cedar Savanna Plant Communities in Point Pelee National Park (Abstract). Department of Biology, York University, North York, Ontario, M3J 1P3, falken@yorku.ca

Fischer, B. C. 1979. Managing light in the selection method. Pages 43-53 *in* Regenerating oaks in upland hardwood forests: Proceedings of the 1979 John S. Wright Forestry Conference, Purdue University, West Lafayette, Indiana.

Foster, D. R., T. Zebryk, P. Scoonmaker and A. Lezberg. 1992. Post-settlement history of human land-use and vegetation dynamics of a *Tsuga canadensis* (hemlock) woodlot in central New England. Journal of Ecology 80:773-786.

Frelich, L, E. 1995. Old forest in the Lake States today and before European settlement. Natural Areas Journal 15(2): 157-167.

Frelich L. E. and C. G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes Region. Ecological Monograph 61: 145-164.

Freemark, K. E. 1989. Landscape ecology of forest birds in the northeast. Pages 7-12 *in* R. M. DeGraaf and W. M. Healy [tech. compilers]. Is forest fragmentation a management issue in the northeast? General Technical Report NE-130. USDA Forest. Service, Northeastern Forest Experiment Station. 32 p.

Friesen, L., M. Cadman, D. Martin, P. Carson, K. Elliott, M. Gartshore, J. McCracken, P. Prevett, B. Stutchbury, D. Sutherland, and A. Woodliffe. (In prep.) National recovery plan for acadian flycatcher and hooded warbler. Recovery of Nationally Endangered Wildlife, Ottawa.

Frothingham, E.H. 1915. The eastern hemlock. Bulletin No. 152. Washington, DC: Forest Service US Department of Agriculture. 43 p.

Gillespie, A.R., and H.W. Hocker. 1986*a*. The influence of competition on individual white pine thinning response. Canadian Journal of Forest Research 16: 1355-1359.

Gillespie, A.R., and H.W. Hocker. 1986*b*. Thinning response of immature white pine. Northern Journal of Applied Forestry 3: 148-150.

Gingrich, S. F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the central states. Forest Science 13: 38-53.

Godman, P. 1992. Applying the shelterwood system Note 2.04. *In* J. G. Hutchinson [ed.]. Northern Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 3 p.

Godman, R. M. and L W. Krefting. 1960. Factors important to yellow birch establishment in Upper Michigan. Ecology 41(1): 18-28.

Godman, R. M., and K. Lancaster. 1990. *Tsuga canadensis* (L.) Carr. Eastern hemlock. Pages 604-612 *in* R. M. Burns and B. H. Honkala [tech. coords.]. Silvics of North America: 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Goodburn, J. M and C. G. Lorimer. 1998. Cavity trees and coarse woody debris in old-growth and managed northern hardwood forests in Wisconsin and Michigan. Canadian Journal of Forest Research 28(3): 427-438.

Gordon, A. G. 1994. The interface of population genetics, genetics, ecology and silviculture: An overview for the boreal forest. Pages152-170 *in* Proceedings of the 1994 Society of American Foresters. Canadian Institute of Forestry Convention, Anchorage, Alaska, Sept. 18-22, 1994.

Gottschalk, K. W. 1988. Gypsy moth and regenerating Appalachian hardwood stands. Pages 241-254 *in* Proceedings, guidelines for regenerating Appalachian hardwood stands, Morgantown, West Virginia. West Virginia University.

Gottschalk, K. W. 1993. Silvicultural guidelines for forest stands threatened by the gypsy moth. General Technical Report NE-171. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 50 p.

Griggs M. M. 1990. *Sassafras albidum* (Nutt.) Nees Sassafras. Pages 773-777 *in* R. M. Burns and B. H. Honkala [tech.coords.]. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Gross, H.L. 1985. White pine blister rust: a discussion of the disease and hazard zones for Ontario. White Pine Symposium Suppl. Proc. Ent. Soc. Ont. 116: 73-79.

Guldin, J. M. 1996. The role of uneven-aged silviculture in the context of ecosystem management. Western Journal of Applied Forestry 11(1): 4-12.

Hannah, P. R. 1988. Re: The shelterwood method in northeastern forest types: A literature review. Northern Journal of Applied Forestry 5: 70-77.

Harrington, C. A. 1984. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research 14: 357-361.

Hart, D. and P. G. Comeau. 1992. Manual brushing for forest vegetation management in British Columbia: A review of current knowledge and information needs. Land Management Report Number 77. British Columbia Ministry of Forests. 36 p.

Heeney, C. J., J. A. Kemperman and G. Brown, G. 1980. A silvicultural guide to the aspen working group in Ontario. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Toronto. 47 p.

Heinen J. T. and T. L. Sharik 1990. The influence of mammalian browsing on tree growth and mortality in the Pigeon River State Forest. American Midland Naturalist 123: 202-206.

Heinselman, M.L., S.S. Frissell Jr., J.R. Habeck, R.W. Mutch, and B.M. Kilgore. 1973. Quaternary-Research 3(3): 317-513.

Heitzman, E., K. S. Pregitzer and O. Miller-Raymond. 1997. Origin and early development of northern white cedar stands in northern Michigan. Canadian Journal of Forest Research 27:1953-1961.

Herr, D. G., L. C. Duchesne, R. Tellier, R. S. McAlpine and R. L. Peterson. 1994. Effect of prescribed burning on the ectomycorrhizal infectivity of a forest soil. International Journal of Wildland Fire 4: 95-102.

Hibbs, D. E. 1982. Gap dynamics in a hemlock-hardwood forest. Canadian Journal of Forest Research 12(3): 522-527.

Hibbs, D. E. and W. R. Bentley. 1983. A management guide for oak in New England. Storrs Connecticut, University of Conneticut Cooperative Extension Services Bulletin 83-12. 12 p.

Hibbs D. E. and W. R. Bentley. 1987. White pine management: Volume and growth. Northern Journal of Applied Forestry 4: 197-201.

Hills, G. A. 1952. The classification and evaluation of site for forestry. Report No. 24. Ontario Department of Lands and Forests, Research Branch. 41 p.

Hills, G. A. 1959. A ready reference to the description of the land of Ontario and its productivity: A compendium of maps, charts, tables and brief comments: preliminary report. Ontario Department of Lands and Forests. 142 p.

Hilt, D. E. 1985. Species composition of young central hardwood stands that develop after clearcutting. Pages 11-14 *in* J. O. Dawson and K. A. Majuerus [eds.]. Proceedings of fifth central hardwoods forest conference at the University of Illinois. Society of American Foresters Publication No. 85-05. University of Illinois, Department of Forestry, Urbana-Champaign, Illinois.

Hobbs, S. D. and M. S. Crawford 1988. The relationship of carbohydrate content of plants to their ability to sprout after mechanical treatment. Forestry Canada, Victoria B.C. FRDA-Report 026.

Holmsen, S. D. 1989. Comparison of chain saws and clearing saws for precommercial thinning in British Columbia. Silviculture Technical Note TN-137, Forest Engineering Research Institute of Canada. 8 p.

Holt, H.A. 1989. Individual tree control. Note 6.10 *in* F. B. Clark and J.G. Hutshinson [eds.]. Central Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 8 p.

Honer, T. G. 1967. Standard volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada. Information Report FMR-X-5. Forest Management Research and Service Institute.

Honer, T. G., M. F. Ker and I. S. Alemdag. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Information Report M-X-140. Fredericton, New Brunswick Maritimes Forest Research Centre. Environment Canada, Canadian Forestry Service. 139 p.

Hornbeck, J.W. and W.B. Leak. 1992. Ecology and management of northern hardwood forests in New England. Gen. Tech. Rep. NE-159. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 44 p.

Hosie, R. C. 1979. Native trees of Canada, 8th edition. Canadian Forestry Service. Fitzhenry & Whiteside Limited, Don Mills. 380 p.

Howse, G.M. and T.Scarr. 1999. Status of important forest pests in Ontario in 1999. Pages 59-82 in Proceedings of 1999 Forest Pest Management Forum, Ottawa, Ontario, November 16-17, 1999.

Hubbard, J. W. 1972. Effects of thinning on growth and yield. Pages 126-130 *in* Aspen: symposium proceedings. General Technical Report NC-1. USDA Forest Service, Washington D.C.

Husch, B., C. I. Miller and T. W. Beers. 1972. Forest mensuration, 2nd edition. New York: The Ronald Press Company. 410 p.

Jacobs, R. D. and R. D. Wray. 1992. Managing oak in the Driftless Area. University of Minnesota Extension Service Publication NR-Bu-5900-S. 32 p.

Jacobson, G. L., Jr., A. Dieffenbacher-Krall. 1995. White pine and climate change. Journal of Forestry 93(7): 39-42.

Jalava, J.V., J. L. Riley, D. G. Cuddy and W. J. Crins. 1997. Natural resources of Ontario: Revised site districts in ecological site regions 6E and 7E, Part I: Rationale and methodology. Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, Ontario 18 p. + map.

Jobidon, R. 1997. Stump height effects on sprouting of mountain maple, paper birch and pin cherry--10-year results. Forestry Chronicle 73:590-595.

Johnson, J. E., J. J. Bollig and R. A. Rathfon. 1997. Growth response of yellow-poplar to release and fertilization. Southern Journal of Applied Forestry 21: 175-179.

Johnson, P. S. 1974. Survival and growth of northern red oak seedlings following a prescribed burn. Research. Note NC-177. USDA Forest Service, Washington, D.C. 3 p.

Johnson, P. S. 1993. Perspectives on the ecology and silviculture of oak-dominated forest in the central and eastern States. General Technical Report NC-153. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 28 p.

Johnson, P. S. 1994. The silviculture of northern red oak. Pages 33-68 *in* J. Timbal and A. Kremer [eds.]. Biology and silviculture of northern red oak in the north central region: A synopsis. General Technical Report NC-173. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 68 p.

Johnson, P. S., C. D. Dale, K. R. Davidson and J. R. Law. 1986. Planting northern red oak in the Missouri Ozarks: A prescription. Northern Journal of Applied Forestry 3: 66-68.

Johnson, P. S. and R. M. Godman. 1983. Precommercial thinning of oak, basswood, and red maple sprout clumps. Pages 124-139 *in* J. C. Stier [ed.]. Proceedings of silviculture of established stands in north central forests. Society of American Forestry Publication No. 83-11, Washington D.C.

Johnson, P. S. and R. Rodgers. 1980. Predicting growth of individual stems within red oak sprout clumps. Pages 420-439 *in* H. E. Garrett and G. S. Cox [eds.]. Proceedings of third central hardwoods conference at Columbia, Missouri. University of Missouri Columbia, Missouri.

Johnson, P. S. and R. Rodgers. 1984. Predicting 25^{th} year diameters of thinned sprouts of northern red oak. Journal of Forestry 82(10): 616-619.

Johnston, W. F. 1977. Manager's handbook for northern white cedar in the north central states. General Technical Report NC-35. USDA. Forest Service, Washington, D.C. 18 p.

Johnston, W. F. 1990. *Thuja occidentalis* L. northern white cedar. Pages 580-589 *in* R. M. Burns, R. M. and B. H. Honkala. Silvics of North America: 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Jones, G. T. 1993. A guide to logging aesthetics--Practical tips for loggers, foresters, and landowners. Northeast Regional Agricultural Engineering Service Cooperative Extension NRAES-60. 28 p.

Jones, R. H., R. R. Sharitz and K. W. McLeod. 1989. Effects of flooding and root competition on growth of shaded bottomland hardwood seedlings. American Midland Naturalist 121(1): 165-175.

Katovich S. and M. Mielke. 1993. How to manage eastern white pine to minimize damage from blister rust and white pine weevil. Technical Bulletin NA-FR-01-93. USDA Forest Service, St. Paul, Minnesota. 14 p.

Kays, J. S. and C. D. Canham. 1991. Effects of time and frequency of cutting on hardwood root reserves and sprout growth. Forest Science 37:524-539.

Keddy, P.A. and C.G. Drummond. 1996. Ecological properties for the evaluation, management, and restoration of temperate deciduous forest ecosystems. Ecological Applications 6(3):

Keddy, C. 1993. Forest history of eastern Ontario. Information Report No. 1, Eastern Ontario Model Forest, Kemptville, Ontario. 46 p. + appendices

Keddy, C. 1994. Forest structure in eastern North America. Information Report No. 9, Eastern Ontario Model Forest, Kemptville, Ontario. 39 p. + appendix.

Kelty, M. J. 1989. Productivity of New England hemlock/hardwood stands as affected by species composition and canopy structure. Forest Ecology and Management 28: 237-257.

Kelty, M.J. 1988. Sources of hardwood regeneration and factors that influence these sources. Pages 17-30 *in* H.C. Smith, A.W. Perkey and w.E. Kidd (eds.). Proceedings of a Workshop on Guidelines for Regenerating Appalachian Hardwood Stands, Morgantown, WV. SAF Publication 88-03.

Kilpatrick H. J., T. P. Husband and C. A. Pringle. 1988. Winter roost site characteristics of eastern wild turkeys. Journal of Wildlife Management 52: 461-463.

Kittredge, D. B., Jr., P. M. S. Ashton. 1990. Natural regeneration patterns in even-aged mixed stands in southern New England. Northern Journal Of Applied Forestry 7:163-168.

Kochenderfer J. N. and J. D. Helvey. 1989. Forest access roads. Note 11.03 *in* F. B. Clark and J.G. Hutshinson [eds.]. Central Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 4 p.

Korstian, C. F. 1927. Factors controlling germination and early survival in oaks. Yale University School of Forestry Bulletin 19. 115 p.

Kowal, D. M., T. P. Husband. 1996. Characteristics of trees with excavated cavities used by birds in Rhode Island. Northern Journal of Applied Forestry 13(1): 16-18.

Kozlowski, T.T. and S.G. Pallardy. 1997. Physiology of woody plants, second edition. Academic Press, San Diego. 411 p.

Kurzava, L. M. and D. J. Mladenoff. 1999. A comparison of old growth and managed forests in Wisconsin and Upper Michigan (Abstract) presented at the Eastern Old Growth Forest Conference, June 9-11, Duluth, Michigan.

Laidly, P. R. 1979. Metric site index curves for aspen, birch, and conifers in the Lake States. General Technical Report NC-54. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 15 p.

Laidly, P. R. 1990. *Populus grandidentata* Michx. Bigtooth aspen. Pages 544-550 *in* R. M. Burns and B. H. Honkala [tech. coords.]. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Lamson, N. I. 1988. Precommercial thinning and pruning of Appalachian stump sprouts - 10-year results. Southern Journal of Applied Forestry 12(1): 23-27.

Landowner Resource Centre. 1996. Restoring old-growth features to managed forests in southern Ontario, Extension Note. Manotick, Ontario. 8 p.

Larsen, D. R. and P. S. Johnson. 1998. Linking the ecology of natural oak regeneration to silviculture. Forest Ecology and Management 106: 1-7.

Larson, B., J. L. Riley, E. Snell and H. G. Godschalk. 1999. The woodland heritage of southern Ontario - a study of ecological change, distribution and significance. Federation of Ontario Naturalists. 262 p.

Larsson, C. 1968. Silver maple thinning. Unpublished File Report, Ontario Department of Lands and Forests. Unnumbered pages.

Larsson, C. 1982. A silvicultural planting key for lowland sites in southern Ontario. Ontario Ministry of Natural Resources, Forest Research Information Paper No. 103. 35 p.

Larsson, C. and P. Jaciw. 1959. Silvics and silviculture of silver maple. Unpublished File Report, Ontario Department of Lands and forests. 35 p.

Law, J. R. and C. G. Lorimer. 1989. Managing uneven-age stands. Note 6.08 *in* F. B. Clark and J.G. Hutshinson [eds.]. Central Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 6 p.

Lawson, E. R. 1990. *Juniperus virginiana* L. eastern red cedar. Pages 131-140 *in* R. M. Burns and B. H. Honkala. [tech. coords.]. Silvics of North America: 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Leak, W. B. and S. M. Filip. 1977. Thirty-eight years of group selection in New England northern hardwoods. Journal of Forestry 75: 641-643.

Leak, W. B. and J. H. Gottsacker. 1985. New approaches to uneven-aged management in New England. Northern Journal of Applied. Forestry 2: 28-31.

Leak, W. B., D. S. Solomon and P. S. DeBald. 1987. Silvicultural guide for northern hardwood types in the northeast. Revised edition. Gen. Tech. Rep. NE-603. USDA Forest Service, Northeast Forest Experiment Station, Upper Darby, Pennsylvania. 36 p.

Leak, W. B., D. S. Solomon and S. M. Filip. 1969. A silvicultural guide for northern hardwoods in the northeast. Gen. Tech. Rep. NE-143. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. 34 p.

Lee, H. T., W. D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological land classification for southern Ontario: First approximation and its application. SCSS Field Guide FG-02. Ontario Ministry Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. 225 p.

Little, S. 1974. Effects of fire on temperate forests: Northeastern United States. Pages 225-250 *in* T. T. Kozlowski and C.E. Ahlgren (eds.). Fire and ecosystems. Academic Press. New York.

Lloyd F. T. and T. A. Waldrop. 1992. Relative growth of oaks and pines in natural mixtures on intermediate to xeric piedmont sites. Pages 196-201 *in* D. Loftis, C. E. McGee. Oak regeneration: Serious problems, practical recommendations. Symposium proceedings. USDA Forest Service General Technical Report SE-84. Asheville, North Carolina. 319 p.

Loftis, D. L. 1983. Regenerating southern Appalachian mixed hardwood stands with the shelterwood method. Southern Journal of Applied Forestry 7: 212-217.

Loftis, D. L. 1985. Preharvest herbicide treatment improves regeneration in southern Appalachian hardwoods. Southern Journal of Applied Forestry 9:177-180.

Logan, K. T. 1965. Growth of tree seedlings as affected by light intensity. I: White birch, yellow birch, sugar maple and silver maple. Canadian Department of Forestry, Publication No. 1121, Ottawa, Ontario. 16 p.

Logan, K. T. 1966. Growth of tree seedlings as affected by light intensity. III: Basswood and white elm. Canadian Department of Forestry Rural Development, Forestry Branch, Publication No. 1176, Ottawa, Ontario. 15 p.

Logan, K. T. 1973. Growth of tree seedlings as affected by light intensity. V: White ash, beech, eastern hemlock and general conclusions. Department of the Environment, Canadian Forestry Service, Publication No. 1323, Ottawa, Ontario. 12 p.

Lorimer, C. G. 1983. Eighty-year development of northern red oak after partial cutting in a mixed-species Wisconsin forest. Forest Science 29(2): 371-383.

Lorimer, C. G. 1989. The oak regeneration problem: new evidence on causes and possible solutions. University of. Wisconsin-Madison Forest. Resources Annals No. 8. Publication R3484. 31 p.

Lotti, T., R. A. Klawitter and W. P. LeGrande. 1960. Prescribed burning for understory control in loblolly pine stands of the coastal plain. Station Paper No. 116. USDA Forest Service, Southeastern Forest Experiment Station. 19 p.

Louter, J.H., M. Kershaw and A.M. Gordon. 1993. The autecology of competing non-crop vegetation on old field sites in southern Ontario. Harris, D. and S. Strobl, (eds.) South. Region Sci. & Tech. Trsfr. Unit, Ontario Ministry of Natural Resources, Brockville, Ont. 143 p.

MacKey, B. G., D. W. McKenney, Y-Q. Yang, J. P. McMahon and M. F. Hutchinson. 1996. Site regions revisited: A climatic analysis of Hill's site regions for the Province of Ontario using a parametric method. Canadian Journal of Forest Research 26(3): 333-354.

Mallik, A.U., K. Wood, C. Hollstedt and M.S. McLaughlan. 1997. Cut stump herbicide treatments to reduce sprouting and root suckering. TN-39, in Bell, F.W., M.S. McLaughlan and J. Kerley (compilers). Vegetation Management Alternatives—A Guide to Opportunities. Ontario Ministry of Natural Resources, Thunder Bay, Ont. 12 p.

Marquis, D. A. 1965. Regeneration of birch and associate hardwoods after patch cutting. Gen. Tech. Rep. NE-32. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. 13 p.

Marquis, D. A. 1967. Clearcutting in northern hardwoods: Results after 30 years. Gen. Tech. Rep. NE-85. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. 13 p.

Marquis, D. A. and R. L. Ernst. 1992. User's guide to SILVAH. Forest Technical Report NE-162. USDA Forest Service, Northeast Forest Experiment Station, Radnor, Pennsylvania. 124 p.

McCaffrey, K. R., J. E. Ashbrenner, W. A. Creed, B. E. Kohn. 1997. The aspen-ruffed grouse connection. Journal of Forestry 95: 16-20.

McCarthy, E. F. and I. H. Simms. 1935. Relation between tree size and mortality caused by fire in southern Appalachian hardwoods. Journal of Forestry 33:155-157.

McCracken, J. 1999. Management of forest interior birds in relation to basal area. Pages 65-66 *in* A. Kettle [compiler]. Southern Ontario woodlands--the conservation challenge. Federation of Ontario Naturalists, Toronto, Ontario.

McCune, B, C. L. Cloonan, and T. V. Armentano. 1988. Tree mortality and vegetation dynamics in Hemmer Woods, Indiana. American Midland Naturalist 120(2): 416-431.

McGee, C. E., D. L. Loftis. 1993. Oak regeneration: a summary. Pages 316-319 *in* D. Loftis and C.E. McGee [eds.]. Oak regeneration: Serious problems, practical recommendations. Symposium proceedings. General Technical Report SE-84. USDA Forest Service, Asheville, North Carolina. 319 p.

McGill, D., J. Martin, R. Rogers and P.F. Johnson. 1991. New stocking charts for northern red oak. Forest Research Note No. 277. University of Wisconsin, Madison,WI. 8 p.

McKibben, B. 1995. An explosion of green. Atlantic Monthly. 275(4): 61-83.

McLaughlan, M.S., Myketa, D., and F.W. Bell. 1996. Managing vegetation with herbicides: a review of glyphosate, 2,4-D, hexazinone, triclopyr and simazine. Nortwest Sci. & Technol. TN-37, in Bell, F.W., M. McLauglan and J. Kerley (compilers).Vegetation Management Alternatives—A Guide to Opportunities. Ont. Min. Natur. Resour., Thunder Bay, Ont. 12 p.

McLaughlin, D., D. Durigon and H. Liljalehto. 1999. Ontario's hardwood forests: Summary of health survey 1986-1998. Pamphlet.

McLean, M.M. 1987. Selection cutting in tolerant hardwoods: Algonquin Park. Ont. Min. Nat. Resourc., Ont. Tree Improv. For. Biomass Inst., Maple, Ont.

Meating, J., O. Van Dyke, A. Boyd and K. Wright. 1999. Management of ice storm damaged woodlots and plantations. SCSS Technical Report #117. South Central Science Section, Science Development and Transfer Branch, Ontario Ministry of Natural Resources, London, Ontario. 96 p.

Methven, I. R. and W. G. Murray. 1974. Using fire to eliminate understory balsam fir in pine management. Forestry Chronicle 50(2): 77-79.

Miller, G. W., K. A. Elliott and E. P. Boysen. 1998. The central Appalachian hardwoods experience provides silvicultural tools for Ontario. SCSS Technical Report No. 005. South Central Science Section, Science Development and Transfer Branch, Ontario Ministry of Natural Resources, London, Ontario. 23 p.

Miller, G. W., T. M. Schuler and H. C. Smith. 1995. Method of applying group selection in central Appalachians hardwoods. Gen. Tech. Rep. NE-696. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 11p.

Miller, R. O. 1992. Ecology and management of northern white cedar. Pages. 1-14 *in* B. Naylor and L Thompson [eds.]. Regenerating conifer cover in deer yards. Technical Report No. 28. Central Ontario Forest Technology Development Unit, Ontario ministry of Natural Resources. 177 p.

Minckler, L. S. and J.D. Woerheide. 1965. Reproduction of hardwoods 10 years after cutting as affected by site and opening size. Journal of Forestry 63(2): 103-107.

Minckler, L. S. 1989. Intensive group selection silviculture in central hardwoods after 40 years. Pages 35-39 *in* G. Rink and C.A. Budelsky [eds.] Proceedings of the seventh central hardwood forest conference, Southern Illinois University at Carbondale, Illinois. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Minckler, L. S., J. D. Woerheide and R. C. Schlesinger. 1973. Light, soil moisture and tree reproduction in hardwood forest openings. Gen. Tech. Rep. NC-89. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 6 p.

Monsanto Canada Inc. 1994. Vision® silviculture herbicide. Commercial product label. Mississauga, Ont. 2 p.

Morawski, Z.J.R. 1971. Hardwood survey in southern Ontario: quality assessment interim report. Toronto: Division of Forestry, Ontario Ministry of Natural Resources.

Mutchmor, A. F. and A. E. Morneault. 1995. Repeat prescribed burns for red oak regeneration. Pages 16-17 *in* Wagner, R. G., L. J. Buse, R. A. Lautenschlager, F. W. Bell, C. Hollstedt, S. Strobl, A. Morneault, W. Lewis and M. T. Ter-Mikaelian [eds.]. Vegetation management alternatives program 1994-1995 annual report. Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario.

Natural Resources Canada. 1994. Tree diseases of eastern Canada. D. T. Myren [ed.]. Natural Resources Canada, Canadian Forest Service, Science and Sustainable Development Directorate. 159 p.

Naylor, B. J. 1994. Managing wildlife in white pine and red pine forests of central Ontario. Forestry Chronicle 70: 411-419.

Naylor, B. J. 1998. Habitat management considerations. Pages 10-1 to 10-31 *in* A silvicultural guide for the tolerant hardwood forest in Ontario. Ontario Ministry of Natural Resources, Queen's Printer for Ontario.

Naylor, B. J. 1999. Tree marking certification course study notes: wildlife habitat concerns. Tree marker trainer course, Ontario ministry of Natural Resources, Westwind Forest Stewardship Inc., Ottawa Valley Forest Inc. 8 p.

Naylor, B. J., J. A. Baker, D. M. Hogg, J. G. McNicol, and W.R. Watt. 1996. Forest management guidelines for the provision of pileated woodpecker habitat, Version 1.0., Ontario Ministry of Natural Resources, Queen's Printer for Ontario. 26 p.

Naylor, B. J., T. Bellhouse, S. Christilaw and P. Weilandt. 1994. Development and validation of a habitat suitability index model for the American marten in central Ontario. Central Region Science and Technology, Ontario Ministry of Natural Resources. Technical Report No. 29. 13 p.

Newcomb, L. 1977. Newcomb's wildflower guide. Little, Brown and Company (Canada) Limited. 490 p.

Nilsson, C.A., R. Lindahl and Å Norström. 1987. Occupational exposure to chain saw exhausts in logging operations. Am. Ind. Hyg. Assoc. J. 48: 99-105.

Novak, M., J. A. Baker, M. E. Obbard and B. Maloch [eds.]. 1987. Wild furbearer management and conservation in North America. The Ontario Trapper Association, Queen's Printer for Ontario, Toronto, Ontario. 1150 p.

Nuzzo, V. 2000. Garlic mustard. Wildflower Winter 2000: 23.

Nyland, R.D. 1987. Selection system and its application to uneven-aged northern hardwoods. Pp. 49-80 In R.D. Nyland (ed.) Managing northern hardwoods: Proceedings of a silvicultural symposium, 23-25 June 1986, Syracuse, NY. Society of American Foresters Publication No 87-03. 430 pp.

Nyland, R. D., L. P. Abrahamson and K. B. Adams. 1983. Use of prescribed fire for regenerating red and white oak in New York. Pages 163-167 *in* America's hardwood forests - opportunities unlimited: Proceedings of the 1982 convention of the Society of American Foresters, Cincinnati, Ohio.

Nyland, R. D. and W. J. Gabriel. 1971. Logging damage to partially cut northern hardwood stands in New York. AFRI Res. Rep. 5. Applied Forest Research Institute, SUNY College of Environmental Science and Forestry, Syracuse New York. 38 p.

Nyland, R. D. and D. A. Marquis. 1978. Appropriate silvicultural systems for northern hardwoods. Pages 334-338 *in* North America's forests: Gateway to opportunity: Proceedings of the 1978 joint convention of Society of American Foresters and the Canadian Institute of Forestry.

Oak, S. W. and D. A. Starky. 1991. Measuring physiological maturity from site quality and age; observations from oak decline areas in southern upland forests. Abstract *in* Southwide forest disease workshop. School of Forestry and Environmental Studies, Duke University, Durham, North Carolina.

Obermeyer, E.L. 1992. Manual vegetation control on the Siuslaw National Forest. *In* Forest Vegetation Management without Herbicides. Oregon State Univ., Dept. of Forestry.

Occupational Health and Safety Act RSO 1990. Queen's Printer for Ontario, Toronto, Ontario.

Ontario Institute of Pedology. 1985. Field manual for describing soils. 3rd edition. Ontario Institute of Pedology, Guelph, Ontario.

Ontario Ministry of Natural Resources. 1983. Management of tolerant hardwoods in Algonquin Provincial Park. Toronto: Forest Resources Branch, Ontairo Ministry of Natural Resources.

Ontario Ministry of Natural Resources. 1986. Managing red pine plantations. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Toronto, Ontario. 134 p.

Ontario Ministry of Natural Resources. 1988. Timber management guidelines for the provision of moose habitat. Wildlife Branch, Ontario Ministry of Natural Resources, Toronto, Ontario. 33 p.

Ontario Ministry of Natural Resources. 1993. The timber resources of Ontario—1993. Policy and Development and Transfer Section, Forest Policy Branch. Queen's Printer for Ontario, Toronto, Ontario. 67 p.

Ontario Ministry of Natural Resources. 1995. Scaling manual, first edition. Queen's Printer for Ontario. 124 p.

Ontario Ministry of Natural Resources. 1996. Prescribed burn planning manual. Aviation, Flood and Fire Management Branch, Ontario Ministry of Natural Resources. Internal Publication No. 313.

Ontario Ministry of Natural Resources. 1997. Silvicultural guide to managing for black spruce, jack pine and aspen on boreal forest ecosites in Ontario. Version 1.1. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto, Ontario. 822 p.

Ontario Ministry of Natural Resources. 1998*a*. A silvicultural guide for the tolerant hardwood forest in Ontario. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto, Ontario. 500 p.

Ontario Ministry of Natural Resources. 1998*b*. A silvicultural guide for the Great Lakes-St. Lawrence conifer forest in Ontario. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto, Ontario. 424 p.

Ontario Ministry of Natural Resources. 1998*c*. Seed zones of Ontario. Policy Directive No. FOR 03 02 06 500. Internal document. Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario.

Ontario Ministry of Natural Resources. 2000. The Ontario tree marking guide. In press. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto, Ontario.

Pearce, C. M. 1992. Pattern analysis of forest cover in southwestern Ontario. The East Lakes Geographer 27: 65-76.

Perala, D. A. 1978. Manager's handbook for aspen in the north central States. Research Note NC-36. USDA Forest Service, Washington D.C. 30 p.

Perala, D.A. 1974. Growth and survival of northern hardwood sprouts after burning. Research Note NC 176 USDA Forest Service, Washington D.C. 4 p.

Perkey A. W., B. L. Wilkins and H. C. Smith. 1993. Crop tree management in eastern hardwoods. Technical Report No. NA-TP-19-93. USDA Forest Service, Northeastern Area State and Private Forestry, Morgantown, West Virginia. 58 p. + appendices.

Philip, M. S. 1994. Measuring trees and forests. 2nd Edition. Wallingford, U.K.: CAP International. 310 p.

Plonski, W. L. 1960. Normal yield tables for black spruce, jack pine, white birch, tolerant hardwoods, white pine and red pine. Ontario Department of Lands and Forests, Toronto, Ontario.

Plonski, W. L. 1981. Normal yield tables (metric) for major forest species of Ontario. Forest Resources Group, Ontario Ministry of Natural Resources, Toronto, Ontario.

Pregitzer, K. S. 1991. The ecology of northern white cedar. Pages 8-14 *in* D. O. Langtane [ed.]. Northern white cedar in Michigan-workshop proceedings, Sault Ste. Marie, Michigan, February 21-22, 1990. Agriculture Experiment Station Research Report 512. 122 p.

Quimby, J. W. 1996. Value and importance of hemlock ecosystems in the eastern United States. Pages 1-8 in S. M. Salom, T. C. Tigner and R. C. Reardon [eds.]. Proceedings of the first hemlock wholly adelgid review. Charlottesville, Virginia. Publication No. FHTET 96-10.

Ranta, B. [ed]. 1998. Identification and ranking of moose aquatic feedings areas (MAFAs). *In S*elected wildlife and habitat features: Inventory manual. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Peterborough, Ontario. 217 p.

Raymond, F. L. and M. M. McLean. 1984. Simulation of growth and yield of hard maple. Timber Sales Branch, Ontario Ministry of Natural Resources, Toronto, Ontario. 36 p.

Reader, R. J. 1987. Loss of species from deciduous forest understory immediately following selective tree harvesting. Conservation Biology 42: 231-244.

Reid, D. J. 1991. Ontario wild turkey status report. Ontario Ministry of Natural Resources, Simcoe, Ontario. 4 p.

Reid, R., R. Symes, and D. van Hemessen. 1996. Towards a conservation strategy for Carolinian Canada—issues and options. 58 p

Rice, J. A., M. E. Woods and B. D. Batchelor. 1998. SCANSS - Silvicultural Calibration of Algoma/North Shore Stands - A Progress Report. SCSS Technical Report 103. South Central Science Section, Ontario Ministry of Natural Resources. 22 p.

Roach, B. 1974. Scheduling timber cutting for sustained yield of wood products and wildlife. Research. Paper NE-14. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. 13 p.

Robb, J. R. and T. A. Bookhout. 1995. Factors influencing wood duck use of natural cavities. Journal of Wildlife Management 59(2): 372-383.

Robinson, S., F. R. Thompson, III, T. M. Donovan, D. R. Whitehead and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Rogers L. L.and E. L. Lindquist. 1992. Supercanopy white pine and wildlife. Pages 39-43 *in* R. A. Stine and M. J. Baughman [eds.]. White pine symposium proceedings: History, ecology, policy and management. University of Minnesota. Report NR-BU-6044-S.

Rose, A. H. and O. H Lindquist. 1980. Insects of eastern larch, cedar and juniper. Canadian Forestry Service Technical Report 28. Department of the Environment, Ottawa, Ontario. 100 p.

Rose A. H. and O. H. Lindquist. 1984. Insects of eastern pines. Canadian Forestry Service Publication 1313, Environment Canada, Ottawa, Ontario. 125 p.

Roth, E. R. and G. H. Hepting. 1969. Prediction of butt rot in newly regenerated sprout oak stands. Journal of Forestry 67(10): 756-760.

Ruark, G. A. 1990. Evidence for the reserve shelterwood system for managing quaking aspen. Northern Journal of Applied Forestry 7: 58-62.

Rudolf, P. O. 1990. Red pine. Pages 442-455 *in* R. M. Burns and B. H. Honkala [tech. coords.]. Silvics of North America; 1. Conifers. Agriculture Handbook 654 USDA Forest Service, Washington D.C. 675 p.

Runkle, J. R. 1985. Disturbance regimes in temperate forests. Pages 17-33 *in* S. Pickett, S. T. A. and P.S. White [eds.]. The ecology of natural disturbance and patch dynamics. Academic Press, New York.

Runkle, J.R. and T.C. Yetter. 1987. Treefalls revisited: gap dynamics in the southern Appalachians. Ecology 68(2): 417-424.

Safford, L. O., J. C. Bjorkbom and J. C. Zasada. 1990. *Betula papyrifera* Marsh. paper birch. Pages 158-169 in R. M. Burns and B. H. Honkala [tech. coords.]. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Sampson, T. L., J. P. Barrett and W. B. Leak 1983. A stocking chart for northern red oak in New England. Research Paper 100. Agricultural Experiment Station, University of New Hampshire, Durham, New Hamphsire. 14 p.

Sander, I. L. 1977. Manager's handbook for oaks in the North Central States. Gen. Tech. Rep. NC-37. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 35 p.

Sander, I. L. 1979. Regenerating oaks with the shelterwood system. Pages 54-60 *in* Proceedings of the 1979 John S. Wright Forestry Conference, Regenerating oaks in upland hardwood forests. Purdue University, West Lafayette, Illinois.

Sander, I. L. 1989. How to assess oak regeneration potential in the Missouri Ozarks. Note 3.03 *in* F. B. Clark and J.G. Hutshinson [eds.]. Central Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 6 p.

Sander, I. L. and F. B. Clarke. 1971. Reproduction of upland hardwood forests in the Central States. USDA Handbook 405. USDA Forest Service, Washington D.C. 25 p.

Sander, I. L., P. S. Johnson and R. Rogers. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. Gen. Tech. Rep. NC-251. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 16 p.

Sander, I. L., P. S. Johnson and R. F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. General Technical Report NC-23. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 7 p.

Sauer, L. J. and Andropogon Associates. 1998. The once and future forest. Island Press, Washington, D.C. 381 p.

Schaffer, W. W. 1996. Silvicultural guidelines for the eastern white cedar. Technical Report TR-006. Southern Region Science and Technology Transfer Unit, Ontario Ministry of Natural Resources, Peterborough, Ontario. 62 p.

Schier, G. A., W. D. Shepperd and J. R. Jones. 1985. Regeneration. Pages 197-208 *in* N. V. DeByle and R. P. Winokur. Aspen: Ecology and management in the western United States. General Technical Report RM-119, USDA Forest Service, Washington, D.C.

Schmidt, K. A. and C. J. Whelan. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. Conservation Biology 13:1502-1506.

Schuler, T.M. and G.W. Miller. 1995. Shelterwood treatments fail to establish oak reproduction on mesic forest sites in West Virginia. Pages 375-387 *in* K. W. Gottschalk and S.L.C. Fosbroke [eds.]. General Technical Report NE-197. Proceedings of the 10th central hardwood Conference, 1995 March 5-8, Morgantown, West Virginia. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania.

SER (Society for Ecological Restoration)—Ontario Chapter. 1999. 1999-2000 Native Plant Resource Guide for Ontario—sources of planting materials for ecological restorationists in Ontario. 24 p.

Smalley 1975 (see Anderson & Rice p. 137 of guide

Smith D.J., Woods M.E. 1997. Red pine and white pine density management diagrams for Ontario. Ontario Ministry of Natural Resources, Southcentral Sciences Section Technical Report # 48. XX p.

Smith, D.M. 1986. The practice of silviculture. 8th edition. New York: John Wiley & Sons. 578 p.

Smith, D. M. and P. M. S. Ashton. 1993. Early dominance of pioneer hardwood after clearcutting and removal of advance regeneration. Northern Journal of Applied Forestry 10:14-19.

Smith D.M. and R.S. Seymour. 1985. Relationship between pruning and thinning. Pages 62-66 *in:* Eastern White Pine: Today and Tommorrow: Symposium Proceedings. USDA Forestry Service General Technical Report # WO-51.

Smith, H.C. 1989. Wild grapevine management. Note 6.13 *in* F. B. Clark and J.G. Hutshinson [eds.]. Central Hardwood Notes. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 4 p.

Smith, H. C. and G. W. Miller. 1987. Managing Appalachian hardwood stands using four regeneration practices- 34 year results. Northern Journal of Applied Forestry 4: 180-185.

Smith, P., and E.L. Borczon. 1977. Managing for deer and timber. Your Forests 10(1): 1-12.

Smyth, J. H. and I. A. Nausedas. 1981. Rural lands and landowners of Ontario: A private land forestry perspective. Joint publication of Canadian Forestry Service and the Ontario Ministry of Natural Resources. 77 p. + appendices.

Solomon, D. S., D. A. Herman and W. B. Leak 1995. FIBER 3.0: An ecological growth model for northeastern forest types. General Technical Report. 73 p.

Soper, J. H. and M. L. Heimburger. 1990. Shrubs of Ontario, 3rd printing. Royal Ontario Museum, Toronto, Ontario. 495 p.

Sork, V. L., J. Bramble and O. Sexton. 1993. Ecology of mast-fruiting in three species of North American deciduous oaks. Ecology 74(2): 528-541.

Souto, D., T. Luther and B. Chianes. 1996. Past and current status of HWA in eastern and Carolina hemlock stands. Pages 9-12 *in* S. M. Salom, T. C. Tigner and R. C. Reardon [eds.]. Proceedings of the first hemlock wholly adelgid review. Charlottesville, Virginia. Publication No. FHTET 96-10.

Stabb, M. 1996. Ontario's old growth: A learner's handbook. Canadian Nature Federation, Ottawa, Ontario. 47 p.

Staley, R. N. 1991. Wood - take a stand and make it better. Ontario Ministry of Natural Resources, Queen's Printer for Ontario. 45 p.

Starkey, D. A., S. W. Oak and G. W. Ryan. 1989. Evaluation of oak decline areas in the South. Protection Report R8-PR-17. USDA Forest Service, Southern Region, Atlanta, Georgia. 36 p.

Steingraber S. K. 1990. Deer browsing, plant competition and succession in a red pine forest, Itasca State Park, Minnesota. Dissertation-Abstracts-International. B. Sciences and Engineering. 50 (8): 3286B-3287B.

Stoeckeler, J. H. 1947. When is plantation release most effective? Journal of Forestry 45: 265-271.

Strobl, S. 1999. Glossy buckthorn treatments tested (Ontario). Ecological Restoration 17(1&2): 88-89.

Stroempl, G. 1972. Some ecological aspects of American basswood. Pages 58-70 *in* The management of southwestern Ontario hardwoods. Great Lakes Forest Research Centre, Canadian Forestry Service, Sault Ste. Marie, Ontario.

Stroempl, G. 1983. Thinning clumps of northern hardwood stump sprouts to produce high quality timber. Forest Research Information Paper No. 104. Ontario Ministry of Natural Resources, Maple, Ontario. 27 p.

Szuba, K. and B. Naylor. 1998. Forest raptors and their nests in central Ontario—a guide to stick nests and their users. SCSS Field Guide FG-03. South Central Science Section, Ontario Ministry of Natural Resources, 78 p.

Taylor, E. P. and R. K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology. Unnumbered pages.

Trimble, G. R., Jr. 1973. The regeneration of central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practice. Research. Paper NE-282. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. 15 p.

Trimble, G.R., Jr., J.J. Mendel, and R.A. Kennell. 1974. A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines. Res. Pap. NE-292. Northeastern Forest Experiment Station, Upper Darby, Pennsylvania. Pages?

Tryon, E. H. and R. P. True. 1964. Relative susceptibility of Appalachian hardwood species to spring frosts occurring after bud break. Bulletin No 503. West Virginia University Agricultural Experiment Station, Morgantown, West Virginia. 15 p.

Tubbs, C. H. 1977*a*. Natural regeneration of northern hardwoods in the northern Great Lakes Region. Gen. Tech. Rep. NC-150. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 20 p.

Tubbs, C. H. 1977*b*. Manager's handbook for northern hardwoods in the North Central States. General Technical Reprot NC-39. US Department of Agriculture, Forest Service, North Central Forest Experiment Station St. Paul, MN.

Tworkoski T. J., D. W. Smith and D. J. Parrish. 1986. Regeneration of red oak, white oak and white pine by underplanting prior to canopy removal in the Virginia Piedmont. Southern Journal of Applied Forestry 16: 206-210.

Tyrrell, L. E. and T. R. Crow. 1994. Dynamics of dead wood in old-growth hemlock-hardwood forests of northern Wisconsin and northern Michigan. Canadian Journal of Forest Research 24: 1672-1683.

Vanclay, K. J. 1994. Modelling forest growth and yield. Applications to mixed tropical forests. Oxon, UK: CAB International. 312 p.

Vanclay, K. J., and N. B. Henry. 1988. Assessing site productivity of indigenous cypress pine forest in southern Queensland. Commonwealth Forestry Review 67: 53-64.

Van Deelen, T. R., K. S. Pregitzer, and J. B Haufler. 1996. A comparison of presettlement and present-day forests in two northern Michigan deer yards. American Midland Naturalist 135: 181-194.

Van Ryn, D. M. and J. P. Lassoi. 1987. Managing small woodlands for firewood. Cornell Cooperative Extension Publication Info. Bulletin 208: 18-21.

Van Wagner, C. E. 1963. Prescribed burning experiments in red and white pine. Publication 1020. Canadian Department of Forestry, Forest Research Branch, Ottawa, Ontario. 27 p.

Voigt, D., J. D. Broadfoot,and J. A. Baker. 1997. Forest management guidelines for the provision of white-tailed deer habitat, Version 1.0. Queen's Printer for Ontario, Toronto, Ontario. 33 p.

Wagner, R. G., L. J. Buse, R. A. Lautenschlager, F. W. Bell, C. Hollstedt, S. Strobl, A. Morneault, W. Lewis and M. T. Ter-Mikaelian [eds.]. 1995. Vegetation management alternatives program. 1994-95 Annual Report. Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario. 99 p.

Waldron, G., M. Gartshore and K. Colthurst. 1996. Pumpkin ash, *Fraxinus profunda*, in southwestern Ontario. Canadian Field Naturalist 110(4): 615-619.

Walsh, M. 1980. Logging damage survey Weldwood's License Livingstone Twp. File Report. Ontario Ministry of Natural Resources, Bracebridge, Ontario. 11 p.

Wargo, P. M. and R. A. Haack. 1991. Understanding the physiology of dieback and decline diseases and its management implications for oak. In: S. B. Laursen, S. B. and J. F. Deboe [eds.]. Conference proceedings: The oak resource in the Upper Midwest, implications for management; 1991 June 3-6, Winona, Maine. University of Minnesota Extension Service, St. Paul, Minnesota. Publication NR-BU-5663-S: 147-158.

Watt, W. R., J. A. Baker, D. M. Hogg, J. G. McNicol and B. J. Naylor. 1996. Forest management guidelines for the provision of marten habitat, Version 1.0. Queen's Printer for Ontario, Toronto, Ontario 26 p.

Webb, S. L. 1999. Disturbance by wind in temperate zone forests. Pages 187-222 *in:* L.R. Walker, [ed.]: Ecosystems of Disturbed Ground. Elsevier Press, Amsterdam.

Weber, M. G. 1991. Aspen management options using fire or cutting. Information Report PI-X-100. Petawawa National Forestry Institute, Forestry Canada, Chalk River, Ontario. 11 p.

Weber M.G., McAlpine R.S., Wotton B.M., Donnelly J.G., Hobb M.W. 1995. Prescribed burning and disk trenching effects on early plantation performance in eastern Ontario. Forest Ecology and Management 78: 159-171.

Weigel, D. and G.R. Parker, 1997. Tree regeneration response to the group selection response in southern Indiana. Northern Journal of Applied Forestry 14: 90-94.

Wendel G.W., and H.C. Smith.1990. White Pine. Pages 476-488 *in: in* R. M. Burns, R. M. and B. H. Honkala. Silvics of North America: 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington, D.C. 675 p.

Williams, P. A. and B. D. Bricker. 1992. Niagara escarpment woodlots management pilot project. Unpublished. Report to the Niagara Escarpment. Commission and Ontario Heritage Foundation. 54 p.

Williams, P. A., A. M. Gordon and E. P. Taylor. 1990. Site index curves and site factors affecting the growth of white pine in southern Ontario. Northern Journal of Applied Forestry 7:163-168.

Williamson, M. J. 1957. Silvical characteristics of eastern red cedar. USDA Forest Service, Central Forest Experiment Station, St. Paul, Minnesota. 14 p.

Wolf, W. W., Jr. 1988. Shelterwood cutting to regenerate oaks - the Glatfelter experience. Pages 210-218 *in* Proceedings of the guidelines for regenerating Appalachian hardwood stands. Society of American Forestry Publication. 88-03.

Woodley, S. and G. Forbes G. [eds.]. 1997. Forest management guidelines to protect native biodiversity in the Fundy Model Forest. New Brunswick Co-operative Fish & Wildlife Research Unit, University of New Brunswick, Fredericton, New Brunswick. 36 p.

Woods, M., J. Rice and E. Boysen. 1998. Stand growth and yield in: A silvicultural guide for the tolerant hardwood forest in Ontario, Version 1.1. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto, Ontario. 500 p.

Common to Latin Name Index

Amphibians, Fish and Reptiles
Birds
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Amphibians, Fish and Reptiles

Common Name	***Latin Name***
American Toad	*Bufo americanus*
Blue-spotted Salamander	*Ambystoma laterale*
Gray Treefrog	*Hyla chrysoscelis*
Red-spotted Newt	*Notophthalmus viridescens viridescens*
Spring Peeper	*Pseudacris crucifer*
Two-lined Salamander (Northern)	*Eurycea bislineata*
Wood Frog	*Rana sylvatica*
Black Rat Snake	*Elaphe obseleta obseleta*
Brown Snake	*Storeria dekayi*
Garter Snake (Eastern)	*Thamnophis sirtalis sirtalis*
Milk Snake	*Lampropeltis triangulum*
Redbelly Snake	*Storeria occipitomaculata*
Brook Trout	*Salvelinus fontinalis*

Birds

Common Name	***Latin Name***
Acadian Flycatcher	*Empidonax virescens*
American Redstart	*Setophaga ruticilla*
Bald Eagle	*Haliaeetus leucocephalus*
Barred Owl	*Strix varia*
Black Tern	*Chlidonias niger*
Black-capped Chickadee	*Parus atricapillus*
Blue Jay	*Cyanocitta cristata*
Boreal Chickadee	*Parus hudsonicus*
Broad-winged Hawk	*Buteo platypterus*
Cape May Warbler	*Dendroica tigrina*
Cerulean Warbler	*Dendroica cerulea*
Chickadees	*Parus* spp.
Common Goldeneye	*Bucephala clangula*
Common Grackle	*Quiscalus quiscula*
Common Redpoll	*Carduelis flammea*
Cooper’s Hawk	*Accipiter cooperii*
Crossbills	*Loxia* spp.
Crow (American)	*Corvus brachyrhynchos*
Dark-eyed Junco	*Junco hyemalis*
Goshawk (Northern)	*Accipiter gentilis*
Great Horned Owl	*Bubo virginianus*
Grosbeak (family)	Fringillidae
Eagles (subfamily)	Buteoninae
Evening Grosbeak	*Hesperiphona vespertina*
Falcons	*Falco* spp.
Finches (family)	Fringillidae
Hairy Woodpecker	*Picoides villosus*
Hawks (family)	Accipitridae
Herons (family)	Ardeidae
Hooded Warbler	*Wilsonia citrina*
Hungarian Partridge	*Perdix perdix*
Loggerhead Shrike	*Lanius ludovicianus*
Long-eared Owl	*Asio otus*
Louisiana Waterthrush	*Seiurus motacilla*
Magnolia Warbler	*Dendroica magnolia*

***Birds** continued*

Common Name	***Latin Name***
Merlin	*Falco columbarius*
Northern Bobwhite Quail	*Colinus virginianus*
Northern Goshawk	*Accipiter gentilis*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Owls (family)	Strigidae
Pileated Woodpecker	*Dryocopus pileatus*
Pine Grosbeak	*Pinicola enucleator*
Pine Siskin	*Carduelis pinus*
Pine Warbler	*Dendroica pinus*
Prothonotary Warbler	*Protonotaria citrea*
Purple Finch	*Carpodacus purpureus*
Raven (Common)	*Corvus corax*
Red Crossbill	*Loxia curvirostra*
Red-shouldered Hawk	*Buteo lineatus*
Robin (American)	*Turdus migratorius*
Ring-necked Pheasant	*Phasianus colchicus torquatus*
Ruby-crowned Kinglet	*Regulus calendula*
Ruffed Grouse	*Bonasa umbellus*
Sapsucker (Yellow-bellied)	*Sphyrapicus varius*
Scarlet Tanager	*Piranga olivacea*
Sharp-shinned Hawk	*Accipiter striatus*
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Sparrow (family)	Fringillidae
Spruce Grouse	*Dendragapus canadensis*
Veery	*Catharus fuscescens*
Vireos	*Vireo* spp.
Waxwings	*Bombycilla* spp.
White-breasted Nuthatch	*Sitta carolinensis*
Wild Turkey	*Meleagris gallopavo*
Woodcock (American)	*Philohela minor*
Wood Duck	*Aix sponsa*
Wood Thrush	*Hylocichla mustelina*
Woodpecker (family)	Picidae
Yellow-bellied Sapsucker	*Sphyrapicus varius*

Insects

Common Name	***Latin Name***
Acorn Weevils	*Curculio* spp.
Ash Borer (Banded Ash Clearwing)	*Podosesia aureocincta*
Asian Long-horned Beetle	*Anoplophora glabripennis*
Asiatic Oak Beetle	*Cyrtepistomus castaneus*
Asiatic Oak Weevil	*Cyrtepistomus castaneus*
Basswood Leafminer	*Baliosus nervosus*
Black Carpenter Ant	*Campontus pennsylvanicus*
Bromegrass Seed Midge	*Stenodiplosis bromicola*
Carpenterworm	*Prionoxystus robiniae*
Eastern Tent Catepillar	*Malacosoma americanum*
Edwards Hairstreak Butterfly	*Satyrium edwardsii*
European Elm Bark Beetle	*Scolytus multistriatus*
European Pine Shoot Moth	*Rhyacionia buoliana*
European Spruce Sawfly	*Diprion hercyniae*
Fall Webworm	*Hyphantria cunea*
Flatheaded Appletree Borer	*Chrysobothris femorata*
Forest Tent Caterpillar	*Malacosoma disstria*
Giant Swallowtail	*Papilio cresphontes*
Gypsy Moth	*Lymantria dispar*
Hackberry Butterfly	*Asterocampa celtis*
Hemlock Looper	*Lambdina fiscellaria*
Hemlock Wooly Adelgid	*Adelges tsugae*
Hickory Bark Beetle	*Scolytus quadrispinosus*
Hickory Nut Weevil	*Curculio caryae*
Hickory Shuckworm	*Laspeyresia caryana*
Hickory Spiral Borer	*Agrilus arcuatus torquatus*
Larch Casebearer	*Coleophora laricella*
Larch Sawfly	*Pristiphora erichsonii*
Large Aspen Tortrix	*Choristoneura conflictana*
Linden Looper	*Erannis tilaria*
Oak Leafshredder	*Croesia semipurpurana*
Olive Hairstreak	*Mitoura grynea*

Insects *continued*

Common Name	***Latin Name***
Oystershell Scale	*Lepidosaphes ulmi*
Pales Weevil	*Hylobius pales*
Pecan Weevil	*Curculio caryae*
Pine Engraver Beetle	*Ips pini*
Pine False Webworm	*Acantholyda erythrocephala*
Pine Shoot Beetle (exotic)	*Tomicus piniperda*
Promethea Moth	*Callosamia promethea*
Redheaded Pine Sawfly	*Neodirprion lecontei*
Red Oak Borer	*Enaphalodes* spp.
Saratoga Spittlebug	*Aphrophora saratogensis*
Spicebush Swallowtail Butterfly	*Battus philenor (Papilio troilus)*
Spruce Budworm	*Choristoneura fumiferana*
Spruce Cone Maggot	*Hylemya anthracina*
Spruce Seed Moth	*Laspeyresia youngana*
Spruce Spider Mite	*Oligonychus ununguis*
Sugar Maple Borer	*Glycobius speciosus*
Walnut Caterpillar	*Datana integerrima*
West Virginia White Butterfly	*Artogeia (pieris) virginiensis*
White Pine Cone Borer	*Eucosma tocullionana*
Zimmerman Pine Moth	*Dioryctria zimmermoni*
White Pine Weevil	*Pissodes strobi*
Willow Flea Weevil	*Rhynchaenus rufipes*
Willow Shoot Sawfly	*Janus abbreviatus*
Woolly Adelgids	*Adeleges* spp.
Zebra Swallowtail Butterfly	*Papilio marcellus*

Plants

Common Name	*Latin Name*
Birch (family)	Betulaceae
Bracken (family)	Dennstaedtiaceae
Evening-primrose (family)	Onagraceae
Fireweed	*Epilobium augustifolium*
Grass (family)	Poaceae
Sedge (family)	Cyperaceae
Alternate-leaved Dogwood	*Cornus alternifolia*
American Beech	*Fagus grandifolia*
American Chestnut	*Castanea dentata*
American Elm	*Ulmus americana*
American Ginseng	*Panax quinquefolius*
American Hazelnut	*Corylus americana*
American Mountain-ash	*Sorbus americana*
American Sycamore	*Platanus occidentalis*
Arrowwood, Southern	*Viburnum recognitum*
Ash	*Fraxinus* spp.
Autumn Olive	*Elaeagnus umbellata*
Balsam Fir	*Abies balsamea*
Balsam Poplar	*Populus blasamifera*
Barberry	*Berberis thunbergii* or *B. vulgaris*
Basswood	*Tilia americana*
Beaked Hazel	*Corylus cornuta* ssp. *cornuta*
Beech	*Fagus grandifolia*
Bellworts	*Uvularia* spp.
Big Shellbark Hickory	*Carya laciniosa*
Birches	*Betula* spp.
Bitternut Hickory	*Carya cordiformis*
Black Ash	*Fraxinus nigra*
Black Birch	*Betula lenta*
Black Cherry	*Prunus serotina*
Black Gum	*Nyssa sylvatica*
Black Locust	*Robinia pseudo-acacia*

***Plants** continued*

Common Name	*Latin Name*
Black Maple	*Acer saccharum* ssp. *nigrum*
Black Oak	*Quercus velutina*
Black Spruce	*Picea mariana*
Black Walnut	*Juglans nigra*
Bloodroot	*Sanguinaria canadensis*
Blue Ash	*Fraxinus quadrangulata*
Bluebead Lily	*Clintonia borealis*
Blue Beech	*Carpinus caroliniana* ssp *virginiana*
Blueberries	*Vaccinium* spp.
Blue Cohosh	*Caulophyllum thalictroides*
Bracken Fern	*Pteridium aquilinum*
Bristle-leaved Sedge	*Carex eburnea*
Brome Grasses	*Bromus inermis or B. tectorum*
Buckthorn	*Rhamnus* spp.
Buffalo-berry	*Shepherdia canadensis*
Bur Oak	*Quercus macrocarpa*
Bush Honeysuckle	*Diervilla lonicera*
Butternut	*Juglans cinerea*
Canada Bluegrass	*Poa compressa*
Canada Blue-joint grass	*Calamagrostis canadensis*
Canada Mayflower	*Maianthemum canadense*
Cedars	*Thuja* spp.
Celandine	*Chelidonium majus*
Cherries	*Prunus* spp.
Cherry Birch	*Betula lenta*
Chinquapin Oak	*Quercus muhlenbergii*
Choke Cherry	*Prunus virginiana*
Common Buckthorn	*Rhamnus cathartica*
Common Hackberry	*Celtis occidentalis*
Common Hop-tree	*Ptelea trifoliata*
Common Juniper	*Juniperus communis*
Cottonwood	*Populus deltoides* ssp. *monilifera*

Plants *continued*

Common Name	***Latin Name***
Cucumber Tree (Cucumber Magnolia)	*Magnolia acuminata*
Currants	*Ribes* spp.
Dame's Rocket	*Hesperis matronalis*
Dandelion (Common)	*Taraxacum officinale*
Dog's-tooth Violet	*Erythronium americanum*
Dog-strangling Vine	*Vincetoxicum rossicum (Cynanchum nigrum)*
Dogwood (family)	Cornaceae
Downy Arrowwood	*Viburnum rafinesqunianum*
Dutchman's-breeches	*Dicentra cucullaria*
Dwarf Chinquapin Oak	*Quercus prinoides*
Dwarf Hackberry	*Celtis tenuifolia*
Dwarf Raspberry	*Rubus pubescens*
Eastern Cottonwood	*Populus deltoides* ssp. *deltoides*
Eastern Dwarf Mistletoe	*Arceuthobium pusillum*
Eastern Flowering Dogwood	*Cornus florida*
Eastern Hemlock	*Tsuga canadensis*
Eastern Red Cedar	*Juniperus virginiana*
Eastern White Cedar	*Thuja occidentalis*
Eastern White Pine	*Pinus strobus*
Elderberry (American Elder)	*Sambucus canadensis*
Elderberry (Red-berried Elder)	*Sambucus racemosa* ssp. *pubens*
Elms	*Ulmus* spp.
Enchanter's Nightshade	*Circaea lutetiana* ssp. *canadensis*
European Buckthorn	*Rhamnus cathartica*
European Guelder Rose	*Viburnum opulus*
European Mountain-ash	*Sorbus aucuparia*
Evening Primrose (family)	*Onagraceae*
Fir	*Abies* spp.
Fire Cherry	*Prunus pensylvanica*
Flat-top Aster	*Aster umbellatus*
Flowering Dogwood	*Cornus florida*
Foam Flower	*Tiarella cordifolia*
Fowl Manna Grass	*Glyceria striata*

***Plants** continued*

Common Name	***Latin Name***
Garlic Mustard	*Alliaria officinalis*
Gaywings	*Polygala paucifolia*
Ginseng	*Panax* spp.
Glossy Buckthorn	*Rhamnus frangula*
Goldenseal	*Hydrastis canadensis*
Goldthread	*Coptis trifolia*
Gooseberry (family)	Grossuliaceae
Gooseberry	*Ribes* spp.
Goutweed	*Aegopodium podagraria*
Grape (family)	Vitaceae
Grass (family)	Poaceae
Gray Birch	*Betula populifolia*
Green Ash	*Fraxinus pennsylvanica*
Hackberry	*Celtis occidentalis*
Hard Maple	*Acer saccharum* ssp. *saccharum or A. saccharum* ssp. *nigrum*
Hart's Tongue Fern	*Phyllitis scolopendrium*
Hawthorn	*Crataegus* spp.
Hazel	*Corylus* spp.
Heath (family)	Ericaceae
Hemlock	*Tsuga* spp.
Hepatica	*Hepatica* spp.
Hickories	*Carya* spp.
High Bush Cranberry	*Viburnum trilobum*
Honey Locust	*Gleditsia triacanthos*
Honeysuckle (family)	Caprifoliaceae
Honeysuckles (non-native)	*Lonicera tatarica,*
Hop-tree	*Ptelea trifoliata*
Ironwood	*Ostrya virginiana*
Jack Pine	*Pinus banksiana*
Jack-in-the-pulpit	*Arisaema atrorubens*
Japanese Knotweed	*Polygonum cuspidatum*
Junipers	*Juniperus* spp.
Kentucky Coffee-tree	*Gymnocladus dioicus*

Plants *continued*

Common Name	*Latin Name*
Large-tooth Aspen	*Populus grandidentata*
Low Sweet Blueberry (Lowbush Blueberry)	*Vaccinium angustifolium*
Manitoba Maple	*Acer negundo*
Maple (family)	Aceraceae
Maple-leaved Viburnum	*Vibernum acerifolium*
Marginal Woodfern	*Dryopteris marginalis*
Marsh Fern	*Thelypteris palustris*
Moneywort	*Lysimachia nummularia*
Mountain Maple	*Acer spicatum*
Multiflora Rose	*Rosa multiflora*
Northern Hawthorn	*Crataegus dissona*
Northern Pin Oak	*Quercus ellipsoidalis*
Northern Red Oak (Red Oak)	*Quercus rubra*
Norway Maple	*Acer platanoides*
Oaks	*Quercus* spp.
Ohio Buckeye	*Aesculus glabra* var.*glabra*
Oriental Bittersweet	*Celastrus orbiculatus*
Ostrich Fern	*Matteuccia struthiopteris*
Paper Birch	*Betula papyrifera*
Partridgeberry	*Mitchella repens*
Pawpaw	*Asimina triloba*
Peach-leaved Willow	*Salix amygdaloides*
Pignut Hickory	*Carya glabra*
Pine	*Pinus* spp.
Pin Cherry	*Prunus pensylcanica*
Pin Oak	*Quercus palustris*
Pitch Pine	*Pinus rigida*
Poison Ivy	*Toxicodendron radicans*
Poplars	*Populus* spp.
Prickly Ash	*Zanthoxylum americanum*
Prickly Gooseberry	*Ribes cynosbati*
Prickly (Wild) Rose	*Rosa acicularis* ssp. *sayi*

***Plants** continued*

Common Name	***Latin Name***
Privet	*Ligustrum vulgare*
Pumpkin Ash	*Fraxinus profunda*
Puttyroot	*Aplectrum hyemale*
Ram’s-head Lady’s Slipper	*Cypripedium arietinum*
Raspberries	*Rubus* spp.
Red Alder	*Alnus rubra*
Red Ash (Green Ash)	*Fraxinus pennsylvanica*
Red Baneberry	*Actaea rubra*
Red Elderberry	*Sambucus pubens*
Red Maple	*Acer rubrum*
Red Mulberry	*Morus rubra*
Red Oak	*Quercus rubra*
Red Osier Dogwood	*Cornus stolonifera*
Red Pine	*Pinus resinosa*
Red Spruce	*Picea rubens*
Riverbank Grape	*Vitis riparia*
Rock Elm	*Ulmus thomasii*
Rose (family)	Roscaeae
Rough-leaved (Mountain) Rice Grass	*Oryzopsis asperifolia*
Rough-stemmed Goldenrod	*Solidago rugosa*
Rue (family)	Rutaceae
Sassafras	*Sassafras albidum*
Scotch Pine	*Pinus sylvestris*
Sedge (family)	Cyperaceae
Sensitive Fern	*Onoclea sensibilis*
Serviceberry	*Amelanchier* spp.
Shagbark Hickory	*Carya ovata*
Sheep Laurel	*Kalmia angustifolia*
Shellbark Hickory	*Carya laciniosa*
Showy Mountain-ash	*Sorbus decora*
Showy Orchis	*Orchis spectabilis*
Shumard Oak	*Quercus shumardii*
Siberian Elm	*Ulmus pumila*

***Plants** continued*

Common Name	***Latin Name***
Silver Maple	*Acer saccharinum*
Skunk Cabbage	*Sympalocarpus foetidus*
Slippery Elm	*Ulmus rubra*
Smooth Alder	*Alnus serrulata*
Smooth Brome	*Bromus inermis*
Smooth Serviceberry	*Amelanchier laevis*
Solomon's Seal	*Polygonatum multiflorum*
Southern Arrowwood	*Vibernum dentatum*
Speckled Alder	*Alnus incana* spp. *rugosa*
Spicebush	*Lindera benzoin*
Spinulose Woodfern	*Dryopteris spinulosa*
Spotted Touch-me-not	*Impatiens capensis*
Spring Beauty	*Claytonia* spp.
Spruces	*Picea* spp.
Squirrel-corn	*Dicentra canadensis*
Starflower	*Trientalis borealis*
Strawberries	*Fragaria* spp.
Striped Maple	*Acer pennsylvanicum*
Sugar Maple	*Acer saccharum* spp. *saccharum*
Swamp Maple	*Acer freemanii*
Swamp White Oak	*Quercus bicolor*
Sycamore	*Platanus occidentalis*
Tamarack	*Larix laricina*
Tartarian Honeysuckle	*Lonicera tatarica*
Thimbleberry (Black Raspberry)	*Rubus occidentalis*
Toothworts	*Dentaria diphylla* or *D. laciniata*
Trembling Aspen	*Populus tremuloides*
Trilliums	*Trillium* spp.
Trout Lilies	*Erythronium* spp.
Tulip Tree	*Liriodendron tulipifera*
Velvet Ash	*Fraxinus velutina*
Velvet-leaf Blueberry	*Vaccinium myrtilloides*
Violets	*Viola* spp.

Plants *continued*

Common Name	***Latin Name***
Virginia Creeper	*Parthenocissus quinquefolia*
Virginia Spring Beauty (Narrow-leaved Spring Beauty)	*Claytonia virginica*
White Ash	*Fraxinus americana*
White Birch	*Betula papyrifera*
White Elderberry (Common Elder)	*Sambucus candensis*
White Elm	*Ulmus americana*
White Mulberry	*Morus alba*
White Oak	*Quercus alba*
White Pine	*Pinus strobus*
White Poplar	*Populus alba*
Woolly-headed Willow	*Salix eriocephala*
White Spruce	*Picea glauca*
White Trillium	*Trillium grandiflorum*
Wild Geranium	*Geranium maculatum*
Wild Grape	*Vitis* spp.
Wild Leek	*Allium tricoccum*
Wild Oatgrass	*Danthonia compressa*
Wild (Red) Raspberry	*Rubus idaeus* ssp. *melanolasius*
Wild Sarsaparilla	*Aralia nudicaulis*
Willow (family)	Salicaceae
Willows	*Salix* spp.
Wintergreen	*Gaultheria procumbens*
Witch-hazel	*Hamamelis virginiana*
Woodferns	*Dryopteris* spp.
Yellow Birch	*Betula alleghaniensis*
Yellow Dogtooth Violet (Yellow Adder's Tongue; Trout Lily)	*Erythronium americanum*
Yellow Poplar	*Liriodendron tulipifera*
Zigzag Goldenrod	*Solidago flexicaulis*

Plant Diseases

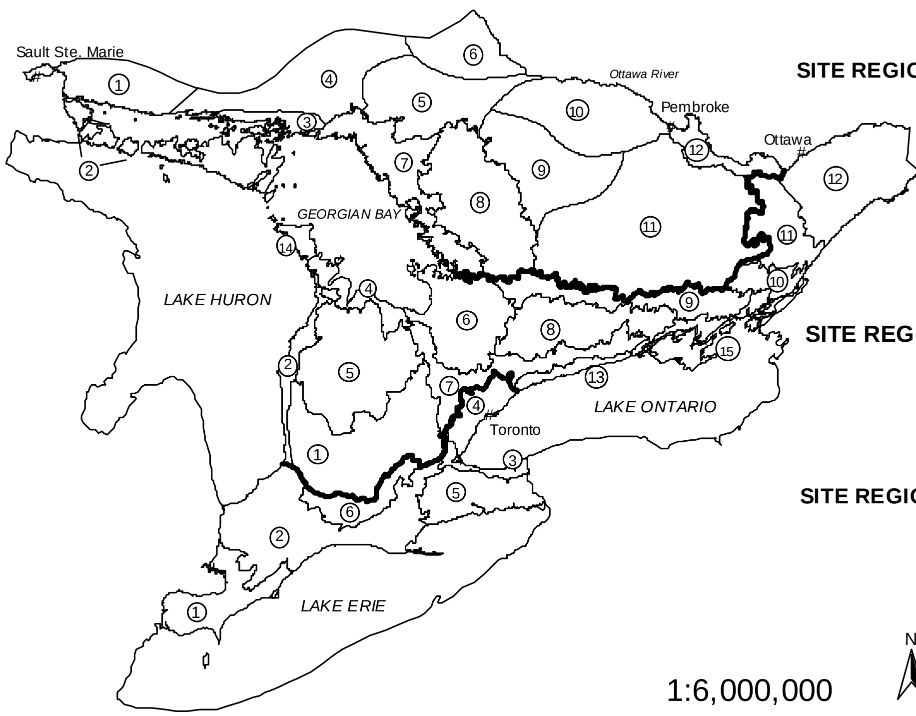
Common Name	***Latin Name***
Artist's Conk	*Ganoderma applanatum*
Beech Bark Disease	*Nectria coccinea* var. *faginata*
Black knot (of cherry)	*Apiosporina morbosa*
Butternut Canker	*Sirococcus clavigignenti-juglandacearum*
Cedar Apple Rust	*Gymnosporangium juniperivirginianae*
Chestnut Blight Fungus	*Cryphonectria parasitica*
Clinker Fungus	*Inonotus obliquus*
Coal Fungus	*Hypoxylon deustum*
Cobra Canker	*Eutypella parasitica*
Dutch Elm Disease	*Ceratocystis ulmi*
False Tinder Fungus	*Phellinus igniarius*
Flowering Dogwood Anthracnose	*Discula destructiva*
Fomes Root rot	*Heterobasidion annosum*
Hedgehog Fungus	*Hericium erinaceous*
Hop Hornbeam Anthracnose	*Gnomoniella carpinea*
Hypoxylon Canker	*Hypoxylon mammatum*
Ink Spot	*Ciborinia whetzelii*
Mossy-top Fungus	*Oxyporus populinus*
Oat Crown Rust	*Puccinia coronata* f.sp. *avenae*
Punk Knot	*Polyporus glomeratus*
Red Ring Rot	*Phellinus pini* and *Haematostereum sanguinolenta*
Root Rot Fungi	*Armilaria complex*
Sap Streak Disease	*Ceratocystis coerulescens*
Scleroderris Canker	*Gremeniella abietina*
Spine-tooth Fungus	*Climacodon septrionalis*
Target Canker	*Nectria galligena*
Tinder Fungus	*Fomes fomentarius*
Varnish Conk	*Ganoderma tsugae*
Wheat Stem Rust	*Puccinia graminis* f.sp.*tritici*
White Heart Rot	*Poria spiculosa*
White Pine Blister Rust	*Cronartium ribicola*
Yellow Cap Fungus	*Pholiota* spp.

Mammals

Common Name	***Latin Name***
Bats (family)	Vespertilionidae
Beaver	*Castor canadensis*
Black Bear	*Ursus americanus*
Coyote	*Canis latrans*
Deer (White-tailed)	*Odocoileus virginianus*
Deer Mouse	*Peromyscus maniculatus*
Eastern Chipmunk	*Tamias striatus*
Eastern Cottontail Rabbit	*Sylvilagus floridanus*
Eastern Gray Squirrel	*Sciurus carolinensis*
Fisher	*Martes pennanti*
Fox	*Vulpes* spp.
Gray Wolf (Eastern)	*Canus lupus lycaon*
Gray Wolf (Northern)	*Canus lupus occidentalis*
Lynx	*Lynx canadensis*
Marten (Pine)	*Martes americana*
Meadow Vole	*Microtus pennsylvanicus*
Mice (family)	Cricetidae
Mink	*Mustela vison*
Moose	*Alces alces*
Opposum (Virginia)	*Didelphis marsupialis*
Otter (River)	*Lontra canadensis*
Porcupine	*Erythizon dorsatum*
Rabbit (family)	Leporidae
Raccoon	*Procyon lotor*
Red Fox	*Vulpes fulva*
Red Squirrel	*Tamiasciurus hudsonicus*
Shrews	*Sorex* spp.
Silver-haired Bat	*Lasionycteris noctivagans*
Snowshoe Hare	*Lepus americanus*
Southern Flying Squirrel	*Glaucomys volans*
Squirrels	*Sciuris* spp. or *Tamiasciurus* spp.
Striped Skunk	*Mephitis mephitis*
Weasel (family)	Mustelidae
White-tailed Deer	*Odocoileus virginianus*
Wolf	*Canus* spp.
Woodland Caribou	*Rangifer tarandus caribou*

Appendix A

Site District Descriptions



APPENDIX A

LANDFORM CHARACTERISTICS OF THE SITE DISTRICTS OF SITE REGIONS 6E AND 7E

Site Districts of Site Region 6E[1]

Stratford North (6E01[2])	"A plain characterized by smooth clay areas and gently rolling loam moraines. All materials are deep and of moderate lime content."[3] The southern part of Hills (1959) site district 6E01 is now mapped as a separate site district (7E06) in Site Region 7.
Kincardine (6E02)	"A plain of lake-laid clay and silt of moderate lime content with local areas of high lime till and low lime sand."
(Wiarton) (6E03)	This site district of Hills (1959) has been subsumed into adjacent site districts (primarily 6E04) and so is not shown on the map.
Meaford (6E04)	Upland area of limestone and shale bedrock thinly (above the escarpment) to deeply (mostly below the escarpment) covered with stony high lime (dolomitic) loam and clay. Site district as currently mapped includes much of Hills' (1959) Site District 6E03
Mount Forest (6E05)	"A moderately rolling upland area of high lime stony loam, gravel and sand derived from dolomitic (calcium and magnesium) limestone." This large site district includes several drumlin fields and moraine complexes.
Barrie (6E06)	"An area of low lime, water-laid clay silt and sand broken by ridges of high lime and low lime loam and sandy loam." The site district includes the Simcoe Lowlands, Schomburg Clayplain, and the western portion of the Peterborough Drumlin Field.
Uxbridge (6E07)	"An area of deep, very high lime sand and gravel, overlain locally by very high lime clay, silt and loam." Deep glacial and proglacial deposits associated with the Oak Ridges Moraine.
Peterborough (6E08)	An area of very high lime loam (drumlinized till) with local areas of high to moderately low lime, water-laid silt and clay. Includes most of the Peterborough Drumlin Field.
Madoc (6E09)	"An area of high lime, stony loamy till with outcrops of shallowly covered limestone and trains of siliceous and low-base sand." Includes the Dummer Moraine, Carden Limestone Plain and much of the Napanee Limestone Plain.
Westport 6E10	"A broken area of shallowly covered bedrock of three types, viz. (i) siliceous igneous rock, (ii) low-base metamorphic rock, and (iii) Paleozoic sandstone. Local pockets of moderate to low lime loam, silt and clay." The north part of Hills (1959) site district (which contains much of the siliceous igneous rock) has been moved to Site Region 5.
Smith Falls (6E11)	"Limestone and sandstone plains with ridges of siliceous igneous bedrock. Shallow to deep deposits of siliceous and moderate to high lime loam, silt and clay."
Kemptville (6E12)	"A plain of limestone and sandstone bedrock covered shallowly to deeply with siliceous and low- base sand, low-base silt and moderate to high lime clay and loam." Champlain Sea sediments (clays and sands) dominate most of the site district, together with some areas of glacial tills.
Oshawa-Coburg (6E13)	Deep, often drumlinized, tills and water-sorted sands and gravels associated with the south slope of the Oak Ridges moraine and the Lake Iroquois Plain. Included by Hills (1959) in Site District 7E04.
Tobermory (6E14)	Thinly soiled dolomitic limestone plain which slopes gently from the escarpment on the Georgian Bay shore to the Lake Huron shore. Hills (1959) included most of this site district in 5E02.
Picton (6E15)	"A shallowly covered limestone plain with local areas of low lime to low-base clay and high lime loamy till." This site district was initially placed in Site Region 7E by Hills (1959); includes Prince Edward Peninsula and part of Napanee Limestone Plain

Site Districts of Site Region 7E[1]

Chatham (7E01)	"A smooth plain of moderate lime clay broken by ridges of sand and gravel."
ST. Thomas (7E02)	"A smooth plain of moderate lime clay overlain in many places by thin to moderately deep deposits of low-base and somewhat argillaceous sand." Includes Norfolk and Bothwell Sand Plains. Haldimand Clay Plain has been moved to a new site district (7E05).
Grimsby (7E03)	"The Niagara Escarpment with lower slopes and adjacent clay plain. Materials are moderate to high lime."
Toronto (7E04)	"A plain of water-laid and ice-laid deposits of clay and loam, moderate to high in lime content". In Hills (1959) this site district (called Whitby) included most of what is now known as Site District 6E13. The site district is dominated by the Peel Plain.
Niagara (7E05)	Primarily a plain of water-laid clay (Haldimand Clay Plain); formerly part of Hills' (1959) Site District 7E02.
Stratford South (7E06)	Formerly part of Site District 6E01 in Hills, 1959: "A plain characterized by smooth clay areas and gently rolling loam moraines. All materials are deep and of moderate lime content"

[1] From Hills (1959), as modified by Jalava et. al. 1997
[2] Numbers refer to Figure 4.5; the site region has been included as part of the number in the table.
[3] Descriptions in quotations are taken directly from Hills, 1959

Appendix B
Autecology of Southern Ontario Tree Species

Table B-1: Definitions used in the following tables.

Tree Longevity (years)	maximum age individuals known to attain, followed by the typical lifespan for most individuals
Fruiting Age (years)	approximate age at which individuals begin producing seed and the age range of maximum production
Seedcrop Periodicity (years)	number of years between bumper crops of seed
Flower Type	monoecious: male and female flowers found on same tree dioecious: male and female flowers found on different trees perfect: flowers contain both male and female structures polygamo-monoecious: some perfect flowers found on monoecious trees polygamo-dioecious: some perfect flowers found on dioecious trees
Seed Dispersal	time of year seed is released form the parent tree
Dispersal Method	the way in which seed is dispersed from the parent tree
Dispersal Distance	maximum distance seed has been reported from parent tree; for most species, seed will fall close to the parent tree
Seed Weight	a relative description of seed weight
Seed Production	where possible the amount of seed produced for a species; many species only have production estimates
Seed Dormancy	the state that prevents germination under environmental conditions unfavourable for growth
Seed Stratification	a pregerminative treatment to break dormancy in seeds and promote rapid uniform germination
Seed Longevity (in soil seed bank)	the maximum amount of time that a seed can remain viable in the leaf litter
Germination Rate	the percent of seed that will germinate from viable seed during the normal period of germination under artificial conditions unless otherwise stated
Seed Pests	biological and environmental conditions that affect seeds; fungus on seeds is not listed since it is common to most tree species
Seedling Pests	biological and environmental conditions that affect seedlings; fungi and damping-off are not listed since they are common problems for most tree seedlings
Sprouting Ability	suckers: vegetative reproduction derived from roots or rhizomes sprouts: vegetative reproduction derived from root collar or lower stems layering: the rooting of an attached branch, lying on or partially buried in soil, which is capable of independent growth after separation from the parent plant
Site: Moisture Requirements	wet: standing water present some time during the growing season an/or poorly drained moist: standing water hardly ever present; soil well-drained and holds moisture dry: no standing water present; soil well-drained and or land sloped and poor moisture holding capacity
Site: Nutrient Requirements	includes soil texture preference and pH optimum ranges
Climatic Range in Ontario	based on the Forest Regions of Canada that occur in Ontario and Hill's Site Regions and Site Districts for Ontario
Genetics	a species' genetic variation or ability to hybridize in Ontario
Seedbed Type	seedbed preference in approximate order of decreasing receptivity
Shade Tolerance	a relative term to express the level of tolerance a species has to shade
Light Requirements	provides information on the level of light required for only those life stages for which information is available
Shade Requirements	provides information on the level of shade required for only those life stages for which information is available
Response to Release	how a seedling, sapling, pole-sized or mature tree responds to release from over-crowded or over-topped conditions
Seed Growing Requirements	provides the best sowing times and conditions to plant seed in a greenhouse or nursery unless otherwise stated
Wildlife Value	whole or parts of trees that provide food, cover and nesting locations for a variety of wildlife species; stands of trees generally provide cover for wildlife
Occurrence	status in Ontario: based on criteria determined by the Natural Heritage Information Centre of the Ministry of Natural Resources status in Canada: based on criteria determined by the Committee on the Status of Endangered Wildlife in Canada
Conservation Concern	conditions that may limit or jeopardize the sustainability of a species or stand
Silvicultural Concern	conditions or special silvicultural considerations that may improve or enhance an individual or stand of trees
Mature Tree Pests	biological conditions that affect mature trees
Other	any other piece of information that does not fit into the specific categories listed above

American Beech

Fagus grandifolia Ehrh.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	400, typically 300	**Site: Moisture Requirements**	- fresh sites - dry-mesic soils in northern part of range
Fruiting Age (years)	40, peaks at 60	**Site: Nutrient Requirements**	- well-drained soils of loamy texture; soils with high humus content are more favorable than lighter soils - pH optimum range 4.1 to 6.0, seldom where pH exceeds 7.0
Seedcrop Periodicity (years)	2-8	**Climatic Range in Ontario**	- all of Deciduous Forest Region - most of Great-Lakes St. Lawrence Forest Region except west of Lake Superior (Site Regions 4E, 4S, 5S)
Flower Type/Pollination Mechanism	monoecious no data	**Genetics**	- only species of *Fagus* genus in North America - northern, southern beeches thought to vary
Seed Dispersal	September to November, after first heavy frost, lasts several weeks	**Seedbed Type**	- mineral/humus mix - germination and survival tend to be better on mor humus than mull humus soil
Dispersal Method	- gravity - rodent caches - blue jay	**Shade Tolerance**	very tolerant
Dispersal Distance	- in vicinity of parent tree - bird dispersal as far as 4 km	**Light Requirements**	seedling: dormancy can be broken in spring, growth prolonged in fall by supplemental light
Seed Weight	heavy	**Shade Requirements**	seedlings: half-day shade for first year; best survival under a moderate canopy or in protected small openings; density decreases with opening size; growth is slow under dense canopy
Seed Production	- no data - seed production better in older stands with high DBH, with large proportion of beech	**Response to Release**	- heavy release reduces growth - high propensity for epicormic branching - heavy cutting or clearcutting reduce numbers in new stand, excessive clearcutting eliminates beech - partial cutting, beech can out-compete intolerant associates
Seed Dormancy	biochemical inhibition, requires stratification	**Seed Growing Requirements**	sow in fall; in spring (if prechilled); cover with 1.25 cm soil; mulch fall-sown beds
Seed Stratification	28 days at 2-5^{o} C	**Wildlife Value**	preferred nest tree of red-shouldered hawk nuts: valuable food source; large quantities of nuts may be consumed by bears prior to, and by deer, after dispersal
Seed Longevity (in soil seed bank)	- < 2 years - not commonly found in seed bank	**Occurrence**	common
Germination Rate	no data	**Conservation Concern**	old-growth beech stands could be seriously threatened by beech bark disease as trees with DBH > 20 cm are particularly vulnerable
Seed Pests	- squirrels, bears, deer, foxes - blue jays, wild turkey - desiccation	**Silvicultural Concern**	spread (from eastern Canada and the northeastern United States) of beech scale insect, *Cryptococcus fagisuga* and concomitant invasion of its feeding sites by the fungi *Nectria coccinea* var. *faginata* or *N. galligena,(*beech bark disease) could seriously jeopardize beech stands in southern Ontario
Seedling Pests	insects	**Mature Tree Pests**	- decay fungi (more than 70 reported)
Sprouting Ability	- sprouts well, ability diminishes after trees reach 10 cm DBH - root suckering almost exclusive form of reproduction in northern part of range - layering, occasionally	**Other**	- highly susceptible to fire damage, flooding, sunscald, logging, pruning - not favoured deer browse - good self-pruner in well-stocked stands - seedlings capable of growing through fern, raspberry cover

American Chestnut[1]

Castanea dentata (Marshall) Borkh.

Biological Features		Ecological Features	
Tree Longevity (years)	300, typically 100	**Site: Moisture Requirements**	dry sites
Fruiting Age (years)	8	**Site: Nutrient Requirements**	- sand, occasionally heavy loams, clays (trees on sandy soils deal better with blight cankers than those on heavier soils) - pH optimum range 4.3-6.4 - soils with alkaline pH may limit distribution
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of natural range - limited to Deciduous Forest Region (Site Region 7E)
Flower Type/Pollination Mechanism	monoecious insects	**Genetics**	- experimental work has been performed to develop blight resistant hybrids - no native hybrids exist - *C. dentata* x *C.mollissima* can occur
Seed Dispersal	late September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - blue jay	**Shade Tolerance**	tolerant
Dispersal Distance	- vicinity of parent tree - further when dispersed by blue jay	**Light Requirements**	able to regenerate under a forest canopy
Seed Weight	heavy	**Shade Requirements**	seedlings: require shade for establishment
Seed Production	variation in yield is exhibited from individual trees, even within same families	**Response to Release**	- able to take advantage of increased light conditions following removals from overhead canopy
Seed Dormancy	- none-slight - stored seed requires stratification if planting occurs following spring	**Seed Growing Requirements**	plant, mulch cured nuts in September to October or plant in spring as early as possible using stratified seed; sow seeds 2.5-5 cm deep, 7.6-10 cm apart natural: sow immediately
Seed Stratification	cure for 1-7 days in cool, well ventilated location then 42 days at 0^o-5^o C in moist medium	**Wildlife Value**	nuts: food source for deer, rodents, birds
Seed Longevity (in soil seed bank)	1 year	**Occurrence**	- rare in Ontario, usually between 21-100 occurrences - threatened in Canada
Germination Rate	artificial: > 80% natural: < 10%	**Conservation Concern**	- need for scientific intervention to assist in overcoming chestnut blight fungus - hypovirulent strains of the pathogen may be a way to control the blight, hybrids - southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- deer, rodents - birds	**Silvicultural Concern**	- it has been confirmed that various oak species are secondary hosts for chestnut blight (has only been found on live, post, scarlet, and white oak) - ongoing forest clearing, loss of habitat are additional threats to its existence
Seedling Pests	chestnut blight	**Mature Tree Pests**	no data
Sprouting Ability	sprouting from stumps has ensured continual existence despite spread of chestnut blight across its range	**Other**	in old-growth stands, direct seeding, rather than vegetative reproduction, remains main source of regeneration

American Mountain-ash

Sorbus americana Marshall

Biological Features		Ecological Features	
Tree Longevity (years)	- short - no other data	**Site: Moisture Requirements**	- wet, acidic cedar and spruce swamps, bogs, stream edges - mesic, upland northern hardwood sites with maple and birch - dry, rocky outcrops
Fruiting Age (years)	15	**Site: Nutrient Requirements**	no data pH optimum range 4.5-5.5
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- Great Lakes-St. Lawrence Forest Region from Lake Ontario, St. Lawrence River northward and westward to Lake Huron, Lake Superior, Moose River drainage system - not in Site Regions 1E, 2E, 2W, 7E
Flower Type/Pollination Mechanism	perfect insect	**Genetics**	shows extensive introgression with showy mountain ash where ranges overlap
Seed Dispersal	August to March	**Seedbed Type**	no data
Dispersal Method	- primarily birds - mammals	**Shade Tolerance**	moderately shade tolerant
Dispersal Distance	in vicinity of parent tree, except when dispersed by birds	**Light Requirements**	no data
Seed Weight	moderate	**Shade Requirements**	no data
Seed Production	no data, yield varies among *Sorbus* species	**Response to Release**	poor
Seed Dormancy	slight	**Seed Growing Requirements**	sow in the fall at shallow depths, mulch
Seed Stratification	90-120 days at 0^{o}-5^{o}C	**Wildlife Value**	ripe fruit, seeds: good food source for birds seedlings: browsed by deer
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	15-20%	**Conservation Concern**	no data
Seed Pests	- mice - birds	**Silvicultural Concern**	no data
Seedling Pests	- deer - Gymnosporangium rust	**Mature Tree Pests**	no data
Sprouting Ability	sprouting occurs	**Other**	- European mountain-ash often mistaken for this species in southern Ontario - seldom reaches tree height (> 6 m) in Ontario - fruit and inner bark may have medicinal uses - generally slow growing

Balsam Fir

Abies balsamea (L.) Miller

Biological Features		Ecological Features	
Tree Longevity (years)	200, typically 125	**Site: Moisture Requirements**	- very moist sites - can grow on dry sites
Fruiting Age (years)	10-15, peaks after 20	**Site: Nutrient Requirements**	- wide range of well-drained inorganic-organic soils - pH optimum range 5.0-7.0
Seedcrop Periodicity (years)	2-4	**Climatic Range in Ontario**	- southern part of Boreal Forest-Barren Region - all of Boreal Forest, Great Lakes-St. Lawrence Forest Regions - absent in Deciduous Forest Region except in York, Durham counties; northern part of Grey, Bruce, Simcoe counties
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	variation in east to west, north to south geographic gradients
Seed Dispersal	September	**Seedbed Type**	- mineral soil - decaying wood - burned duff - pioneer mosses
Dispersal Method	- wind - rodents	**Shade Tolerance**	very tolerant
Dispersal Distance	- mostly 20-60 m - 160 m possible	**Light Requirements**	germination: light required seedlings: 50% sunlight for optimum growth
Seed Weight	light	**Shade Requirements**	germination: some shade to help decrease competition
Seed Production	134 seeds/cone	**Response to Release**	well, even at advanced ages
Seed Dormancy	biochemical inhibition	**Seed Growing Requirements**	sow seeds in fall; cover with 0.6 cm of soil
Seed Stratification	natural: 21-90 days at 5^{o} C artificial: in moist sand for 30 days at 5^{o} C	**Wildlife Value**	- food, cover for many wildlife species - winter cover for deer - bows are preferred deer browse after cutting - buds are minor part of diet for spruce, ruffed grouse
Seed Longevity (in soil seed bank)	~1 year	**Occurrence**	common
Germination Rate	- 25% - ranges from 20-90%	**Conservation Concern**	no data
Seed Pests	- mammals (red squirrel, mice, voles) - birds	**Silvicultural Concern**	- should be marked for removal when managing pine with shelterwood silviculture system as it is a prolific seeder which will compete with desired pine regeneration - widespread death of this species occurs in some parts of northwestern Ontario as a result of spruce budworm infestations
Seedling Pests	- woolly adelgid, hemlock looper - Cytospora dieback - needle blight, needle cast - snow blight - tip blight - Armillaria root disease - crushing from ice, snow	**Mature Tree Pests**	- black bears girdle mature trees - susceptible to spruce budworm
Sprouting Ability	layering: secondary (only in extreme conditions in north part of range)	**Other**	- wind damage especially high in old unmanaged stands - fire prevents regeneration - seedlings have slow initial growth

Balsam Poplar

Populus balsamifera ssp. *balsamifera* L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	200, typically 100	**Site: Moisture Requirements**	fresh to moderately wet
Fruiting Age (years)	8-10	**Site: Nutrient Requirements**	- growth appears to be controlled by nitrogen availability in some stages of succession in combination with light, water, and nutrient availability in other stages - sand, loam, clay - acid intolerant
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	all forest regions
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- only 1 variety, *P. balsamifera* var. *subcordata* occurs in eastern Canada - hybridizes with *P. deltoides* to produce *P. x jackii*
Seed Dispersal	May to July	**Seedbed Type**	mineral soils
Dispersal Method	- wind - water	**Shade Tolerance**	very intolerant
Dispersal Distance	100-200 m, longer distances by water	**Light Requirements**	prefers full sun
Seed Weight	very light	**Shade Requirements**	germination: occurs in dark
Seed Production	prolific, varies from year to year	**Response to Release**	generally poor after even short period of suppression in very intolerant species
Seed Dormancy	none	**Seed Growing Requirements**	do not cover seeds or press into soil; keep moist
Seed Stratification	none required	**Wildlife Value**	buds: food source for ruffed grouse branches: provide food source for deer, moose, elk, beaver; dam material for beaver bark: food for hares, rodents
Seed Longevity (in soil seed bank)	2-4 weeks	**Occurrence**	common
Germination Rate	no data	**Conservation Concern**	no data
Seed Pests	none	**Silvicultural Concern**	- competition from brush and weeds can easily eliminate 1 year-old seedlings - both balsam poplar, *P x jackii* hybrids, susceptible to Septoria canker
Seedling Pests	- small mammals - borers - desiccation during first month of growth - Venturia leaf and shoot blight - Septoria leaf spot and canker - Cytospora canker on saplings - Armillaria root disease in coppice stands	**Mature Tree Pests**	- browsing by deer, moose, caribou - beaver
Sprouting Ability	sprouts, suckers well from roots, stumps, buds, broken twigs, buried stems, branches	**Other**	- resistance to fire increases with age, bark thickness - resistant to damage by browsing - resin content in buds repels hares - good self-pruner - rapid juvenile growth - frost damage (all ages)

Basswood

Tilia americana L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 200, typically 100	**Site: Moisture Requirements**	best on moist sites
Fruiting Age (years)	10, peaks at< 100	**Site: Nutrient Requirements**	- nitrogen demanding; grows poorly on sites deficient in nitrogen - sandy loam, loam, silt loam; obtains maximum development on finer-textured soils - also found on sand dunes, dry exposed rock ridges - pH range 4.5 to 7.5, optimum 7.0
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- Deciduous, Great Lakes-St. Lawrence Regions - includes all of Site Regions 5E, 5S, 6E, 7E
Flower Type/Pollination Mechanism	perfect insects	**Genetics**	a single, but highly variable species
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- wind - birds - rodents	**Shade Tolerance**	mid tolerant
Dispersal Distance	2X tree height, potentially more in higher winds	**Light Requirements**	some light improves growth, development at seedling stage
Seed Weight	light	**Shade Requirements**	seedlings: partial shade aids establishment
Seed Dormancy	- pronounced, impermeable testa - early harvest, immediate sowing overcomes dormancy	**Response to Release**	- release of seedlings after 3 growing seasons improves growth - open-grown trees have short stems, many large branches; dense stands produce straight, columnar trunks with narrow tops
Seed Production	low, in some cases 100% of fruit produce no seed (parthenocarpy)	**Seed Growing Requirements**	sow in early fall, 2X seed diameter; mulch; keep moist; protect from rodents; takes 2 years to germinate
Seed Stratification	110-130 days at 2^o to 5^o C	**Wildlife Value**	nectar: heavy nectar producer; good source for bees; makes good honey seeds: food source for rodents trees: sites for cavity nesters
Seed Longevity (in soil seed bank)	2 years	**Occurrence**	common
Germination Rate	- 20-30% (treated seed) - generally poor regardless of seedbed conditions	**Conservation Concern**	no data
Seed Pests	- mice, squirrels, chipmunks - insects (lepidoptera larvae)	**Silvicultural Concern**	- stumps should be cut low to the ground to encourage regeneration by sprouting - group openings will improve basswood growth in future stand
Seedling Pests	- rabbits - susceptible to girdling by mice, voles - defoliators	**Mature Tree Pests**	- local infestations of defoliators may occur (e.g., linden looper, basswood leafminer) - decay increases significantly after 120 years of age
Sprouting Ability	sprouts well from stumps; sprouts should be thinned before reaching 5 cm DBH	**Other**	- susceptible to fire damage - resistant to spring frosts

Big Shellbark Hickory

Carya laciniosa (Michx. f.) Loudon

Biological Features		Ecological Features	
Tree Longevity (years)	typically 350	**Site: Moisture Requirements**	wet sites
Fruiting Age (years)	40, peaks at 75-200	**Site: Nutrient Requirements**	- specific nutrient requirements unknown - grows well on heavy loams or silt loams - grows best on neutral or slightly alkaline soils
Seedcrop Periodicity (years)	2	**Climatic Range in Ontario**	- at northern part of its natural range - Deciduous Forest Region (Site Districts 7E(1,2,3,5))
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- hybridizes with shagbark, pecan - numerous hybrids of pecan, bitternut, shellbark, shagbark hickories have been described
Seed Dispersal	September to December	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - squirrels, other rodents	**Shade Tolerance**	very tolerant
Dispersal Distance	- vicinity of parent tree - greater distances when transported by animals	**Light Requirements**	seedlings: grow slowly under light shade
Seed Weight	heavy	**Shade Requirements**	reproduces well in partial shade, but growth is slowed under dense canopy
Seed Production	70 to 105 l nuts/tree	**Response to Release**	heavy release sometimes results in epicormic branching
Seed Dormancy	- biochemical inhibition overcome artificial stratification - physical properties of seedcoat overcome by artificial heating of germination beds	**Seed Growing Requirements**	sow untreated nuts in fall at depth 2X nut diameter, mulching necessary until germination complete; sow pretreated nuts in spring at depth 2X nut diameter
Seed Stratification	90-120 days at 2^{o}-5^{o} C	**Wildlife Value**	nuts: food for ducks, quail, wild turkey, squirrels, chipmunks, deer, foxes, raccoons, mice
Seed Longevity (in soil seed bank)	no data	**Occurrence**	rare, usually between 21-100 occurrences in Ontario
Germination Rate	50-75%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - rare in stands, occurs with other hickories and may be overlooked
Seed Pests	- squirrels, other mammals - ducks, wild turkey - pecan weevil, hickory shuckworm	**Silvicultural Concern**	- consider opening the forest canopy (group selection, shelterwood) in areas where a good number of seedlings have established to encourage growth into canopy; monitor seedling response - provide at least 2-sided release to established saplings - overlooked or not recognized by tree-markers
Seedling Pests	hickory spiral borer, flatheaded apple tree borer	**Mature Tree Pests**	leaf disease, stem canker, wood rot, root rot
Sprouting Ability	sprouts readily when cut	**Other**	- susceptible to fire damage

Bitternut Hickory

Carya cordiformis (Wangenh.) K. Koch

Biological Features		**Ecological Features**	
Tree Longevity (years)	> 200, typically 150	**Site: Moisture Requirements**	- moist sites - can grow on dry sites
Fruiting Age (years)	30 years, peaks at 50-125	**Site: Nutrient Requirements**	- grows well on soils low in nutrients - grows on variety of soils - fine loam, sandy soils that have often been burned or plowed
Seedcrop Periodicity (years)	3-5	**Climatic Range in Ontario**	- at northern limit of natural range - all of Deciduous Forest Region - limited in Great Lakes-St. Lawrence River Forest Region to 6E (9,10,11,12,15)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	naturally hybridizes with other hickories
Seed Dispersal	September to December	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - squirrels	**Shade Tolerance**	- intolerant to intermediate - seedlings on bottomlands have higher tolerance
Dispersal Distance	vicinity of parent tree	**Light Requirements**	seedlings: require light
Seed Weight	heavy	**Shade Requirements**	seedling survival poor under a dense canopy
Seed Production	no data	**Response to Release**	- low incidence of epicormic branching - saplings grow quickly after clearcutting
Seed Dormancy	can overcome dormancy by prechilling	**Seed Growing Requirements**	sow seeds in fall to depth of 2X diameter note: deep tap root, for transplanting dig to 60 cm depth after 2-3 years
Seed Stratification	30-60 days at 0.6^{o} -4^{o} C	**Wildlife Value**	limited as food source nuts: less favoured than other hickories bark: occasionally fed on by rabbits, beaver, small rodents
Seed Longevity (in soil seed bank)	1-2 years	**Occurrence**	common
Germination Rate	55%	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- squirrels - birds - hickory nut weevil	**Silvicultural Concern**	tap root makes it difficult to transplant all but youngest trees
Seedling Pests	- not severely affected by disease - weevils (defoliators) - fire - leaf spots and leaf blotch	**Mature Tree Pests**	- hickory bark beetle attacks more serious during drought years - white heart rot
Sprouting Ability	sprouts prolifically from stumps, roots, root	**Other**	- saplings and mature trees easily damaged by fire - best self-pruner of all hickories - less susceptible to frost than other hickories - survives browsing, breakage, drought

Black Ash

Fraxinus nigra Marshall

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	250-300, typically > 50	**Site: Moisture Requirements**	moist to wet sites
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	- requires high nutrient content - common on peat, muck soils - fine sands underlain by sandy till; sand, loam underlain by lake-washed clayey till - pH optimum range 4.4-8.2
Seedcrop Periodicity (years)	3-4	**Climatic Range in Ontario**	- all of Deciduous, Great Lakes-St. Lawrence Forest Regions - Boreal Forest Region (southern parts of Site Regions 2E, 2W)
Flower Type/Pollination Mechanism	polygamous wind	**Genetics**	no known races or hybrids
Seed Dispersal	July to October	**Seedbed Type**	exposed mineral, peat, muck soils
Dispersal Method	wind	**Shade Tolerance**	intolerant
Dispersal Distance	> 150 m	**Light Requirements**	no data
Seed Weight	medium	**Shade Requirements**	germination: requires partial shade
Seed Production	- no specific data - considered average	**Response to Release**	no data
Seed Dormancy	- chemical inhibition, seedcoat effects require warm/prechill stratification - older seed exhibits more dormancy than fresh seed	**Seed Growing Requirements**	fall: sow soon after collection, without prechilling (before October 15, never after November 1); mulch until spring spring: sow pretreated seeds; cover with 1.2 cm sand; keep moist, partially shaded
Seed Stratification	60-90 days at 20^{o}-30^{o} C followed by 90 days at a 5^{o}C	**Wildlife Value**	seeds: important food to game birds, song birds, squirrels, mice young trees: browsed heavily by deer, moose beaver use ash in absence of poplars
Longevity (in soil seed bank)	2-8 years	**Occurrence**	common
Seed Germination Rate	20-75%	**Conservation Concern**	Akwesasne are restoring black ash to preserve their basket weaving culture
Seed Pests	rodents	**Silvicultural Concern**	no data
Seedling Pests	- deer - leaf spot, anthracnose, leaf rust	**Mature Tree Pests**	- deer (intolerant to browsing) - beaver (in areas where poplar are absent)
Sprouting Ability	- readily sprouts from root collar - also known to sucker	**Other**	- slow growing - wood is used in traditional native basket making

Black Cherry

Prunus serotina Ehrh.

Biological Features		Ecological Features	
Tree Longevity (years)	> 250, typically 100	**Site: Moisture Requirements**	- tolerates range of conditions - wet to dry sites - poor growth on very wet, very dry sites
Fruiting Age (years)	10, peaks between 30-100	**Site: Nutrient Requirements**	- prefers deep, infertile, highly acidic, well-drained soils - sandy loam to loam
Seedcrop Periodicity (years)	3-4	**Climatic Range in Ontario**	- at northern limit of natural range - all of Deciduous, Great Lakes-St. Lawrence Forest Regions
Flower Type/Pollination Mechanism	perfect insects	**Genetics**	- 4 varieties of black cherry have been recognized in the southern part of the range - provenance testing has identified several traits that are related to geographic origin
Seed Dispersal	August to September	**Seedbed Type**	- humus - seedlings do not like coniferous litter
Dispersal Method	- gravity - song birds - foxes, bears	**Shade Tolerance**	- intolerant - seedlings are shade tolerant for 3-5 years, but do not persist without overstory release
Dispersal Distance	- vicinity of parent tree - 33-400 m if by birds, mammals	**Light Requirements**	seedlings: require release after 3-4 years; best height growth occurs in full sunlight stump sprouts: grow rapidly in full sun
Seed Weight	light	**Shade Requirements**	germination: best beneath canopy representing 50-70% stocking; decreases at lower canopy densities, poorest in full sunlight
Seed Production	heavy	**Response to Release**	slight to moderate growth increases in dominant, codominant crown classes aged 50-60 years
Seed Dormancy	requires period of after-ripening during winter months on forest floor	**Seed Growing Requirements**	sow seeds in fall to depth of 2X seed diameter in moist, shaded soil
Seed Longevity (in soil seed bank)	> 3 years	**Wildlife Value**	preferred browse of deer bark, seedlings, fruit, seeds: food for wide variety of wildlife
Seed Stratification	120 days at 0^{o}-5^{o} C	**Occurrence**	common
Germination Rate	no data	**Conservation Concern**	no data
Seed Pests	- mammals - birds	**Silvicultural Concern**	- sprouts originating low on stump should not be discriminated against in silvicultural operations - protection from high levels of deer browsing is recommended
Seedling Pests	- deer, rabbits, hares - porcupines, mice, voles girdle stems - eastern tent caterpillar - cherry leaf spot - black knot	**Mature Tree Pests**	- deer browsing - porcupines, mice, voles girdle stems - black knot
Sprouting Ability	readily sprouts from stumps with maximum sprouting by trees <40 years old	**Other**	- flat top aster, rough-stemmed goldenrod, bracken fern, wild oatgrass interfere with establishment; other woodland ferns and grasses may cause a similar reaction - low tolerance to browsing - grows faster than associates in seedling, sapling, pole stages - maintains growth advantage over associated species for 60-80 years; mortality increases after 80-100 - bark fairly resistant to fire; low-intensity fire enhances potential photosynthetic performance - susceptible to damage by storms

Black Gum[1]

Nyssa sylvatica Marshall

Biological Features		**Ecological Features**	
Tree Longevity (years)	> 300	**Site: Moisture Requirements**	- moist to wet sites - has ability to tolerate brief spring flooding
Fruiting Age (years)	usually begins early	**Site: Nutrient Requirements**	- wide variety of sites - light-textured soils, in uplands growth is best on loams - rich, clay loam, in the lower slopes
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- at northern limit of natural range - limited to local areas in Deciduous Forest Region (Site Districts 7E(1,2,3,5)
Flower Type/Pollination Mechanism	polygamo-dioecious insects, primarily bees; wind	**Genetics**	- only 1 variety, black tupelo (var. *sylvatica*) occurs in southern Ontario (i.e., swamp tupelo (var. *biflora*) does not) - no reported races or hybrids
Seed Dispersal	September to November	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - mammals - birds (robins)	**Shade Tolerance**	- tolerant - drops out of canopy after about 70 years
Dispersal Distance	vicinity of parent tree	**Light Requirements**	requires nearly full sunlight for optimal development
Seed Weight	heavy	**Shade Requirements**	no data
Seed Production	highly variable	**Response to Release**	seedlings: > 25% respond favourably saplings/pole-sized: respond favorably to release from overtopping vegetation
Seed Dormancy	moderate dormancy benefiting from cold, moist stratification	**Seed Growing Requirements**	sow directly in fall or stratified seed in spring; 1.3-2.5 cm deep or pressed into soil and mulched
Seed Stratification	30-120 days at 0^o-5^o C	**Wildlife Value**	fruits, seeds, sprouts: excellent food sources for many animals young sprouts: relished by deer trees: good cavity nesting sites
Seed Longevity (in soil seed bank)	no data	**Occurrence**	rare in Ontario, usually between 21-100 occurrences
Germination Rate	no data	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - long-term sustainability of populations depends on documentation, education regarding existence, location, management
Seed Pests	mammals	**Silvicultural Concern**	- protect mature trees in existing stands - management activities, such as the creation of group openings in the vicinity of parent trees, should be undertaken to encourage seedling establishment; monitoring regeneration and follow-up tending required
Seedling Pests	- leaf miners, forest tent caterpillar	**Mature Tree Pests**	susceptible to heart rot fungi
Sprouting Ability	- high sprouting potential from small stumps - low sprouting potential from large stumps - root suckering common - layering is used to produce nursery stock	**Other**	- old trees susceptible to windthrow - damaged by hot fires - root pruning stimulates root growth

[1] *Status Report prepared, April, 1993*

Black Maple

Acer saccharum Marshall ssp. *nigrum* (Michx. f.) Desmarais

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	200	**Site: Moisture Requirements**	- prefers moist sites - may occur on dry exposed limestone sites
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	- moderately well-drained to well-drained - rich low grounds over limestone
Seedcrop Periodicity (years)	4	**Climatic Range in Ontario**	- at northern limit of natural range - all of Deciduous Forest Region - southern part of Great Lakes-St. Lawrence Forest Region includes Site Districts 6E(1, 4, 6, 7, 9,10, 11, 12, 15); 5E (12)
Flower Type/Pollination Mechanism	monoecious wind; bees	**Genetics**	hybridizes readily with sugar maple in eastern part of its range
Seed Dispersal	SeptembertoOctober	**Seedbed Type**	humus/mineral mix
Dispersal Method	- wind - water	**Shade Tolerance**	very tolerant
Dispersal Distance	vicinity of parent tree	**Light Requirements**	no data
Seed Weight	moderately heavy	**Shade Requirements**	seedlings: recommended during period of emergence to establishment; prosper under heavy forest cover
Seed Production	no data	**Response to Release**	good, even after prolonged, extreme suppression
Seed Dormancy	- biochemical inhibition causing deep dormancy, requiring prolonged stratification	**Seed Growing Requirements**	sow in fall, cover with soil at 2X seed diameter (0.5 - 1 cm deep)
Seed Stratification	moist stratification at temperatures slightly above freezing, 35 - 90 days	**Wildlife Value**	seeds: food for birds, small mammals bark: eaten by porcupine, rabbits, mice browsed by deer, rabbits
Seed Longevity (in soil seed bank)	no data	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	- no data specific to species - generally, unstratified maple seeds planted in fall have higher rate than artificially stratified seed	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - of regional significance in parts of range (e.g., eastern Ontario)
Seed Pests	- squirrels, mice - birds	**Silvicultural Concern**	no data
Seedling Pests	- deer, rabbits, squirrels, mice - birds - bud-damaging insects, defoliators - anthracnose, leaf spot, Verticillium wilt	**Mature Tree Pests**	- deer, rabbits (low tolerance to browsing) - stem cankers, heart rot - Nectria canker on saplings
Sprouting Ability	no data	**Other**	- rabbits show preference for certain seedlings in this species eating them every year yet leaving others a few inches away untouched; may be related to smell - black maple sap has highest sugar content of the maples

Black Oak

Quercus velutina Lam.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	200, typically 100	**Site: Moisture Requirements**	best on moist sites
Fruiting Age (years)	20, peaks 40-75	**Site: Nutrient Requirements**	- range of rich soils, heavy clays, loamy sands - grows best on silty clay to loam soils; only grows on lightest, driest sands in Middlesex/Lambton counties - requires acidic soil
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- at northern limit of natural range - all of Deciduous Forest Region - Site Districts 6E(2, 7, 13, 15) in Great Lakes-St. Lawrence Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- hybridizes readily with other species of subgenus *Erythrobalanus*; 13 hybrids known - in Ontario, hybridizes with northern pin, red, Shumard oaks
Seed Dispersal	August to October	**Seedbed Type**	mineral soils
Dispersal Method	- squirrels, mice - gravity - blue jays	**Shade Tolerance**	intermediate
Dispersal Distance	- vicinity of parent tree; may be 2000 m when dispersed by rodents or birds	**Light Requirements**	seedlings: > 10% critical to survival, growth
Seed Weight	moderate, smaller acorns in northern populations	**Shade Requirements**	germination: partial shade beneficial
Seed Production	no data	**Response to Release**	- best response obtained if release begins before age 30 - good if trees are in codominant or above-average intermediate crown classes - epicormic branching occurs except for trees in dominant crown class
Seed Dormancy	slight, requires cold stratification	**Seed Growing Requirements**	sow in fall, cover with firmed soil 2X seed diameter (0.6 cm); responds very well to direct sowing on dry sites natural: undergoes prechilling through fall, germinates in spring
Seed Stratification	30-60 days at 0^{o}-5^{o} C	**Wildlife Value**	larval food plant for Edwards Hairstreak butterfly acorns: valuable food source to squirrels, deer, wild turkey, small rodents
Seed Longevity (in soil seed bank)	6 months	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	no data	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - an indicator species for prairie, savanna; presence may be used to map former distribution of these rare communities
Seed Pests	seed crop may be totally consumed in all but good seed years by deer, squirrels, mice, blue jays, wild turkey, nut weevils	**Silvicultural Concern**	species identification important during tree marking for harvest
Seedling Pests	- deer - gypsy moth - Armillaria, anthracnose, leaf blister, leaf spots - Phytophthora root rot (nurseries) - desiccation, fire	**Mature Tree Pests**	- oak wilt - wildfires - gypsy moth
Sprouting Ability	- ability to sprout declines with age - resprouting of advanced regeneration common following fire, death of top growth	**Other**	Nectria on saplings

Black Spruce

Picea mariana (Miller) B.S.P.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	500, typically 200	**Site: Moisture Requirements**	prefers wet, poorly-drained sites
Fruiting Age (years)	7-19, peaks at 50-150	**Site: Nutrient Requirements**	- organic soils with considerable amount of decayed woody material - pH optimum range 4.0-6.0
Seedcrop Periodicity (years)	2-6	**Climatic Range in Ontario**	- at southern limit of natural range - characteristic of Boreal Forest Region - Great Lakes - St. Lawrence Forest Region - local relict populations in Deciduous Forest Region (Site Region 7E)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybrids of black spruce x red spruce common
Seed Dispersal	- September - accelerated in response to fire	**Seedbed Type**	- mineral soils - sphagnum moss
Dispersal Method	wind	**Shade Tolerance**	tolerant
Dispersal Distance	80 m	**Light Requirements**	seedlings/layerings: develop in 10 % full light intensity, but survival, growth improves in open
Seed Weight	very light	**Shade Requirements**	no data
Seed Production	1,146-2,865 cones/tree	**Response to Release**	- does not increase growth until ~ 2 years after release - complete release results in winter drying
Seed Dormancy	none	**Seed Growing Requirements**	- sow seeds in fall, cover with 2X seed diameter of soil - seed requires 16 days at 20°-30° C to germinate
Seed Stratification	require light for germination	**Wildlife Value**	- important food source, cover for spruce grouse - summer habitats for ruby-crowned kinglet, magnolia warbler, Cape May warbler, ovenbird - food for pine grosbeak, pine siskin, crossbills
Seed Longevity (in soil seed bank)	25 years	**Occurrence**	common
Germination Rate	12%	**Conservation Concern**	hybridization with red spruce
Seed Pests	red squirrel, mice, voles	**Silvicultural Concern**	no data
Seedling Pests	- snowshoe hare - Chrysomyxa rusts - snow blight	**Mature Tree Pests**	- cone-bearing branches eaten by red squirrels - European spruce sawfly - eastern dwarf mistletoe - Chrysomyxa rusts - needle cast
Sprouting Ability	layering, important in many parts of its range, particularly in Boreal Forest Region	**Other**	- requires fire or bog formation for regeneration - does not compete well with balsam fir, northern white cedar, red maple, balsam poplar, black ash after cutting in mixed stands on good peatland sites - slow growing

Black Walnut

Juglans nigra L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tee Longevity (years)	250, typically 150	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	4-6, peaks between 30-130	**Site: Nutrient Requirements**	- sensitive to soil conditions - grows best on deep, fertile, nearly neutral, well-drained soils - growth increases with increased nitrogen - sandy loam, loam, silt loam to silty clay-loam soils - common on limestone soils
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- at northern limit of natural range - limited to all of Deciduous Forest Region, southern edge (Site Region 6E) of Great Lakes-St. Lawrence Forest Region - isolated stands in Ottawa Valley - cultivation by native Americans has influenced distribution
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- shows great variation for growth, survival - 400 culitvars known
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity, - squirrels	**Shade Tolerance**	intolerant
Dispersal Distance	vicinity of parent tree, several kilometers	**Light Requirements**	- seldom found under the shade of dense forest canopies - must be dominant or codominant crown classes to survive
Seed Weight	very heavy	**Shade Requirements**	seedlings: intolerant of shade
Seed Production	112 kg/ha hulled nuts	**Response to Release**	- released trees produce more seeds than unreleased trees - bole sprouting occurs after first release - pole-size trees double growth rate over 10-year period
Seed Dormancy	physical properties of seedcoat may inhibit germination until second spring	**Seed Growing Requirements**	sow in fall immediately after collection or prechill in moist sand, plant in spring 2.5-5 cm deep; protect form rodents, use fungicide
Seed Stratification	- 90 - 120 days at 3^{o}-5^{o}C - necessity, duration varies by seed source	**Wildlife Value**	nuts: provide food for wildlife buds: source of deer browse
Seed Longevity (in soil seed bank)	2-4 years	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	50%	**Conservation Concern**	- the disease agent that causes butternut canker can infect black walnut under artificial conditions; has not yet been observed in nature - southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- squirrels - walnut curculio - mould (stored seed)	**Silvicultural Concern**	planted extensively, but more care is required in choosing appropriate sites
Seedling Pests	- deer, mice, rabbits - walnut caterpillar, fall webworm - root rot (nurseries), mould (nursery storage) - leaf spots	**Mature Tree Pests**	- yellow-bellied sapsucker (may effectively girdle trees with peck holes) - root rot, canker - defoliating insects (walnut caterpillar, fall webworm)
Sprouting Ability	sprouts readily after logging, fire	**Other**	- bark fairly resistant to fire - releases toxin (juglone) found in leaves, bark, nut husks, roots, affecting other plants growing within its root zone - presence of Kentucky coffee-tree is good indicator of good walnut planting site

Black Willow

Salix nigra Marshall

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tee Longevity (years)	85, typically 70	**Site: Moisture Requirements**	- limited to wet soils near water - flourishes at, or below, water-level
Fruiting Age (years)	10, peaks between 25-75	**Site: Nutrient Requirements**	- alluvial flats, sandbars, disturbed areas - common in swamps, sloughs, swales with muck, sand, silt, clay-loams - pH optimum range 6.0-7.5
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of natural range - occurs as scattered individuals in Deciduous Forest Region to Lake Erie to Bruce Pennisula) - also as scattered individuals in Great-Lakes St. Lawrence Forest Region in Ottawa- St. Lawrence lowlands
Flower Type/Pollination Mechanism	dioecious mainly by nectar-seeking insects; also wind	**Genetics**	- exact number of varieties is unclear - doesn't hybridize readily in nature but may do so with peach-leaved willow or other willow shrubs
Seed Dispersal	April to May	**Seedbed Type**	- very moist, exposed mineral soils - very moist , exposed organic soils
Dispersal Method	- wind - water (seeds remain viable longer)	**Shade Tolerance**	very intolerant
Dispersal Distance	great distances by both wind, water	**Light Requirements**	seedlings: full sunlight promotes vigorous growth
Seed Weight	very light	**Shade Requirements**	partial shade required during, after germination
Seed Production	high	**Response to Release**	- epicormic branching under open-grown conditions or when weak trees released - light, early, frequent thinning prevents stagnation, mortality in stands
Seed Dormancy	none known	**Seed Growing Requirements**	artificial: sow immediately after seed dispersal in acid, sand-peat mixture covered with <1.2 cm acid sand, moist natural conditions: requires very moist, almost flooded, exposed mineral soils
Seed Stratification	none required	**Wildlife Value**	sap is food source for yellow-bellied sapsucker
Seed Longevity (in soil seed bank)	only a few days, time is greatly reduced under dry conditions	**Occurrence**	common
Germination Rate	artificial: 70 % natural: ranked as high	**Conservation Concern**	no data
Seed Pests	desiccation	**Silvicultural Concern**	may be confused with Missouri willow
Seedling Pests	leaf rust	**Mature Tree Pests**	- black carpenter ants, willow shoot sawfly, willow flea beetle - willow blight, scab, black canker - prone to breakage
Sprouting Ability	roots sprout prolifically	**Other**	- stands susceptible to hot fires - a favorite for soil stabilization projects because of extensive fibrous root system - bark, leaves once used to treat rheumatism - salicin, a basic ingredient of aspirin was isolated from willow in 1829; modern medicine now synthesizes salicylic acid rather than extracting from natural state - good self-pruner with good soil conditions - fast growing; in favourable conditions seedlings often exceed 1.2 m in height in first year - seldom attains tree size (> 6 m) in Ontario

Blue Ash[1]

Fraxinus quadrangulata Michx.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	300, typically 200	**Site: Moisture Requirements**	- moist to wet sites - of all eastern North American ashes, considered best able to endure dryness
Fruiting Age (years)	25	**Site: Nutrient Requirements**	- rich bottomlands or well-drained sand - floodplains of clay, fine sand, silt - shallow soil over dry limestone
Seedcrop Periodicity (years)	3-4	**Climatic Range in Ontario**	- at northern limit of natural range - restricted to Deciduous Forest Region - specifically Point Pelee, Lake Erie Islands, North Sydenham River watershed, Sydenham River watershed, Thames River watershed, Catfish Creek - artificially established at University of Guelph; shows naturalization of species to that area
Flower Type/Pollination Mechanism	perfect wind	**Genetics**	no known hybridization between blue ash and other species
Seed Dispersal	October to November	**Seedbed Type**	no data
Dispersal Method	- wind - water	**Shade Tolerance**	tolerant
Dispersal Distance	10 m from parent tree by wind, longer distances by water	**Light Requirements**	germination: full sun to half shade seedlings: openings required in forest canopy
Seed Weight	light	**Shade Requirements**	germination: full sun to half shade seedlings; shade for short period after germination
Seed Production	abundant	**Response to Release**	no data
Seed Dormancy	chemical inhibition, physical properties of seedcoat requires warm - cold stratification	**Seed Growing Requirements**	collect, sow seeds as soon as colour changes to yellow-brown (before October 15, not after November 1), sow to depth 2X seed diameter; sow pretreated seeds in spring covered by 0.6-0.8 cm soil
Seed Stratification	60 days at 20^{o}- $30^{o}C$, then 90 days at $5^{o}C$	**Wildlife Value**	seeds, seedlings: provide limited food supply for wildlife
Seed Longevity (in soil seed bank)	several years	**Occurrence**	- vulnerable in Ontario; usually between 21-100 occurrences - threatened in Canada
Germination Rate	no data	**Conservation Concern**	- increasingly rare tree in Canada - southern Ontario range represents ≥ 80% of species' range in Canada - local populations close to roadsides are threatened - floodplain forest clearing reduces suitable habitat
Seed Pests	- small mammals - birds	**Silvicultural Concern**	- protect trees from logging - establish 1X tree height or > group openings up to 100m downwind of mature parent trees; monitoring regeneration and follow-up tending required
Seedling Pests	- deer - ash leaf spot	**Mature Tree Pests**	no data
Sprouting Ability	stump sprouting after harvest	**Other**	

[1] *Status Report prepared, March 1993*

Blue Beech

Carpinus caroliniana Walter ssp. *virginiana* (Marshall) Furlow

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	- in Ontario, dry to moist - other locations, wet to moist
Fruiting Age (years)	15	**Site: Nutrient Requirements**	- rich soils, high in nutrients, organic matter - sand, loam, clay - pH optimum range 4.0-5.6, may be as high as 7.4
Seedcrop Periodicity (years)	3-5	**Climatic Range in Ontario**	- limited to Deciduous Forest Region, southern portion of Great Lakes-St. Lawrence Forest Region (Site Districts 5E(10,11,12); 6E(12, 13, 15))
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	different forms from north to south
Seed Dispersal		**Seedbed Type**	- humus/mineral mix - must protect from extreme changes in temperature
Dispersal Method	- birds - wind	**Shade Tolerance**	- very tolerant - greatest in seedlings, declines with age
Dispersal Distance	- no data - bird dispersal distances greater by wind	**Light Requirements**	no data
Seed Weight	light	**Shade Requirements**	germination, seedlings: requires shade for first year
Seed Production	no data	**Response to Release**	- responds well - no other data
Seed Dormancy	chemical inhibition, physical properties of seedcoat requires stratification	**Seed Growing Requirements**	collect, sow seed while green or prechill, sow following spring; cover with 1.5 cm soil natural: germination often delayed until second year
Seed Stratification	- 18 weeks at 4^{o} C + gibberellic acid treatment - seedcoat scarification + gibberellic acid treatment	**Wildlife Value**	seeds, buds, catkins: eaten by songbirds, ruffed grouse, ring-necked pheasants, bobwhite, wild turkey, fox, gray squirrels leaves, twigs, larger stems: eaten by cottontails, beaver, deer trees: vireo nesting sites
Seed Longevity (in soil seed bank)	several years	**Occurrence**	common
Germination Rate	- variable - 60%, often as low as 1-5% for stratified seed - 100% for green immature seed	**Conservation Concern**	no data
Seed Pests	- squirrels - birds	**Silvicultural Concern**	can replace overstory species lost by logging or catastrophe, preventing larger species from reproducing
Seedling Pests	- deer, but not preferred food - rabbits	**Mature Tree Pests**	no data
Sprouting Ability	stump sprouting, root suckering occurs readily in response to overstory removal	**Other**	- very windfirm - withstands short periods of flooding - resistant to frost damage - susceptible to fire - seldom reaches tree height (> 6 m) in Ontario

Bur Oak

Quercus macrocarpa Michx.

Biological Features		Ecological Features	
Tree Longevity (years)	> 400, typically 200	**Site: Moisture Requirements**	- does well on wide range of moisture conditions - best on moist site - drought resistant - intolerant of flooding
Fruiting Age (years)	35 years, peaks between 75-150	**Site: Nutrient Requirements**	- fertile soils - associated with calcareous soils - pH optimum range 4-7.5
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- all of Deciduous, Great Lakes-St. Lawrence Forest Regions
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- hybridizes with 9 oaks species - northern variety *Q. macrocarpa* var. *olivaeformis*
Seed Dispersal	August to November, generally September	**Seedbed Type**	mineral soils
Dispersal Method	- gravity - squirrels - blue jays - water (limited)	**Shade Tolerance**	intermediate
Dispersal Distance	- vicinity of parent tree - 60-90 m if dispersed by squirrels, further by blue jays	**Light Requirements**	no data
Seed Weight	heavy	**Shade Requirements**	germination, seedlings: partial shade
Seed Production	no data	**Response to Release**	epicormic branching
Seed Dormancy	none	**Seed Growing Requirements**	not normally grown in nurseries; sow seed just below surface in late fall; protect from rodents
Seed Stratification	30-60 days at 0^{o}-5^{o} C	**Wildlife Value**	acorns: valuable food source for red squirrels, blue jays, wood ducks, wild turkey, deer, cottontails, mice, other rodents
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	high	**Conservation Concern**	no data
Seed Pests	- deer, rabbits, squirrels, mice - birds	**Silvicultural Concern**	no data
Seedling Pests	- defoliators - Armillaria - oak anthracnose	**Mature Tree Pests**	- Armillaria, other root rots - defoliators - Nectria canker on saplings
Sprouting Ability	stump sprouting vigorous after logging or fire, but sprout quality, poor	**Other**	- bark highly resistant to fire (most resistant of all oaks) - greatest tolerance of all oaks to urban pollution - slow growing

Butternut

Juglans cinerea L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	75	**Site: Moisture Requirements**	fresh sites
Fruiting Age (years)	20, peaks between 30-60	**Site: Nutrient Requirements**	- fertile, well-drained soils - seldom found on dry, compact or infertile soils
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- all of Deciduous Forest Region - southern portion of Great Lakes-St. Lawrence Forest Region (Site District 5E(11), all of Site Region 6E)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with other species of same genus, except black walnut
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - squirrels, other rodents - water	**Shade Tolerance**	intolerant
Dispersal Distance	vicinity of parent tree unless dispersed by rodents, water	**Light Requirements**	seedlings: require forest gaps for growth
Seed Weight	very heavy	**Shade Requirements**	none
Seed Production	9-35 l/tree	**Response to Release**	no data
Seed Dormancy	biochemical inhibition: needs stratification	**Seed Growing Requirements**	sow in fall with husks removed soon after collection or sow prechilled seed in spring, cover with 2.5-5.0 cm soil; protect from rodents natural: germination occurs in spring following seedfall
Seed Stratification	90-120 days at 20^{o}-30^{o} C	**Wildlife Value**	nuts: food for wildlife
Seed Longevity (in soil seed bank)	2 years	**Occurrence**	common
Germination Rate	65%	**Conservation Concern**	- healthy trees should be protected since few disease-resistant trees have been found - frequently an associate of other rare species; potentially a conservation concern due to butternut canker
Seed Pests	- rodents - common grackle where populations are high - nut weevils	**Silvicultural Concern**	- butternut canker caused by fungus, *Sirococcus clavigignenti-juglandacearum* is serious problem in Ontario - 90% of sites visited have diseased trees that eventually die - identify and report resistant individuals (in stands where diseased individuals also occur) to: *Forest Gene Conservation Association* *Suite 233, 266 Charlotte Street* *Peterborough ON* *K9J 2V4*
Seedling Pests	- defoliators - leaf spot - butternut canker	**Mature Tree Pests**	butternut canker
Sprouting Ability	stumps of young trees, saplings capable of sprouting	**Other**	- releases toxin (juglone) found in the leaves, bark, nut husks, roots, an antagonism between black walnut and other plants growing within its root zone - subject to storm damage, although generally windfirm - very susceptible to damage by fire - fast growing

Cherry Birch[1]

Betula lenta L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 265, typically 150	**Site: Moisture Requirements**	- best on moist sites - performs poorly on excessively dry sites
Fruiting Age (years)	40	**Site: Nutrient Requirements**	- no data - can be found on rocky, coarse, textured or shallow, well-drained soils
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- Deciduous Forest Region - 1 confirmed site in southern Ontario (south shore of Lake Ontario)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- closely related to, can hybridize with yellow birch, F_1 hybrids have low vigour, poor germination rates - no natural hybrids verified
Seed Dispersal	- September to November - secondary seed dispersal could occur over snow	**Seedbed Type**	- mineral soils - decaying wood - humus
Dispersal Method	wind	**Shade Tolerance**	intolerant
Dispersal Distance	> 80 m, particularly over crusted snow	**Light Requirements**	seeds: at least 8 hours/day before germination
Seed Weight	light	**Shade Requirements**	germination: in dark requires 1 month prechilling seedlings: require 2-3 months shade during first summer
Seed Production	unknown	**Response to Release**	no data
Seed Dormancy	biochemical inhibition: requires light	**Seed Growing Requirements**	sow soon after collection in late summer, fall; do not cover, keep moist
Seed Stratification	none required	**Wildlife Value**	seeds, seedlings: food for wildlife
Seed Longevity (in soil seed bank)	no data	**Occurrence**	- extremely rare in Ontario, usually 5 or fewer occurrences in Ontario
Germination Rate	43%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - existing population in Ontario is small, localized - no seedlings observed in Ontario population, but trees are producing seed - 1 site threatened by bank erosion (Lake Ontario); development pressures
Seed Pests	- rodents - birds	**Silvicultural Concern**	would survive well under selection or uniform shelterwood management systems
Seedling Pests	- deer (have preference for seedlings)	**Mature Tree Pests**	Nectria canker
Sprouting Ability	sprouting from small stumps common	**Other**	- may be considered valuable for soil protection because of its ability to grow on marginal, erosion-prone sites - sapling growth rapid - very susceptible to fire damage

[1] *Status Report prepared, November, 1992*

Chinquapin Oak

Quercus muhlenbergii Engelm.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	moderately long-lived	**Site: Moisture Requirements**	dry to moist sites
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	- limestone soils - shallow soil over limestone on Erie Islands, Niagara Escarpment - calcareous sand on Point Pelee, Pinery Provincial Park - pH optimum range 6.5-7.0, also occur on soils with pH > 7.0
Seedcrop Periodicity (years)	infrequent intervals	**Climatic Range in Ontario**	- at northern limit of natural range - limited to the Deciduous Forest Region, small portion of the Great Lakes-St. Lawrence Forest Region near Thousand Islands (Site Districts 6E(7, 9, 10,15))
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with white, swamp white, dwarf chinquapin, bur oaks
Seed Dispersal	September to October	**Seedbed Type**	no data
Dispersal Method	- gravity - rodents - birds (blue jays)	**Shade Tolerance**	- intermediate to intolerant, is less tolerant with age - seedlings tolerate moderate overstory or understory cover but growth is slow
Dispersal Distance	- vicinity of parent tree - greater distances when dispersed by rodents	**Light Requirements**	requires a lot of light
Seed Weight	heavy	**Shade Requirements**	germination: partial shade
Seed Production	no data	**Response to Release**	should respond well
Seed Dormancy	none	**Seed Growing Requirements**	sow immediately in fall at depth 2X acorn diameter
Seed Stratification	none required	**Wildlife Value**	acorns: food for many bird, mammal species seedlings, leaves, twigs: preferred by rabbits
Seed Longevity (in soil seed bank)	until following spring	**Occurrence**	- uncommon to rare in eastern Ontario - uncommon to locally common, demonstrably secure in Ontario
Germination Rate	no data	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- deer, raccoon, rabbits, squirrels, chipmunks, mice, voles - blue jays, wild turkey - acorn weevils, moth larvae, gall-forming cynipids	**Silvicultural Concern**	- during old stand harvest, this species must be present as large, advanced reproduction if it is to be a component of new stand - no reason to discriminate against this species in thinnings
Seedling Pests	- rabbits (seedlings known to survive 3 years after being eaten to ground) - defoliators - Armillaria root disease in trunk sprouts - anthracnose, leaf blister	**Mature Tree Pests**	- gypsy moth - oak wilt (usually kills tree within 2-4 years) - Nectria canker on saplings
Sprouting Ability	sprouts readily	**Other**	- usually found as scattered individuals - growth fast compared to other oaks, similar to white oak on similar sites - seedlings from locally collected seed can grow at rate of 80 cm/year

Common Hackberry

Celtis occidentalis L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	200, typically 150	**Site: Moisture Requirements**	- fresh to wet sites - can withstand periodic flooding - well to imperfectly-drained, but occasionally floodplains
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	- variety of soils - commonly found on fertile, calcareous sand, silt, clay loams shallow soil over limestone - pH 7.2
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- all of Deciduous Forest Region - southeastern part of Great Lakes-St. Lawrence Forest Region (primarily 6E(10,11,12), may extend into 5E(11,12)) - also occurs in Rainy River area in northwestern Ontario - cultivation by native Americans influenced distribution of this species
Flower Type/Pollination Mechanism	polygamo-monoecious wind	**Genetics**	genetic variation probably exists, but has not yet been investigated
Seed Dispersal	October to throughout winter	**Seedbed Type**	humus/mineral mix
Dispersal Method	- birds (during northward migration) - rodents - water	**Shade Tolerance**	intermediate; often more tolerant as seedlings
Dispersal Distance	- vicinity of parent tree - greater distances when transported by birds	**Light Requirements**	no data
Seed Weight	moderate	**Shade Requirements**	no data
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	over-winter while fruits remain on branches exhibit dormancy	**Seed Growing Requirements**	in fall sow immediately at depth of 2X seed diameter; in spring sow stratified seed covered with 1.25 cm soil
Seed Stratification	60-90 days at 3^{o}-5^{o} C	**Wildlife Value**	larval foodplant for provincially rare hackberry butterfly seeds: food for foxes, wild turkey, cedar waxwings, yellow-bellied sapsuckers, robins etc.
Seed Longevity (in soil seed bank)	1-2 years	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	- 20- 30% under natural conditions - 47% under artificial conditions	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - eastern Ontario populations uncommon - provincially rare hackberry butterfly dependents upon the species
Seed Pests	- mammals - birds	**Silvicultural Concern**	tree is becoming popular replacement for elm as shade tree, especially in urban areas where it seems relatively resistant to pollution
Seedling Pests	- gall-producing insects - leaf spot	**Mature Tree Pests**	no data
Sprouting Ability	sprouting from small stumps occurs, rarely form large stumps layering is possible under artificial conditions	**Other**	- highly susceptible to fire damage - growth most rapid between 20-40 years - on poor sites growth is very slow, trees often dwarfed

Common Hop-tree

Ptelea trifoliata L.

BIOLOGICAL FEATURES		**ECOLOGICAL FEATURES**	
Tree Longevity (years)	typically > 20	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	5-8	**Site: Nutrient Requirements**	- sandy, well-drained soils - soils over limestone, may also include clay
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- limited to the Deciduous Forest Region - specifically, north shore of Lake Erie, from Holiday Beach to Hilman March; Erie Islands - cultivated populations also known in southern Ontario
Flower Type/Pollination Mechanism	dioecious insects	**Genetics**	only species of hop-tree found in Canada
Seed Dispersal	September (may persist until spring)	**Seedbed Type**	mineral soils
Dispersal Method	wind	**Shade Tolerance**	intolerant
Dispersal Distance	vicinity of parent tree	**Light Requirements**	flowering: requires full sun seedlings: require light for establishment
Seed Weight	light	**Shade Requirements**	none
Seed Production	- ~300,000 seeds/ha - considered abundant seeder	**Response to Release**	no data
Seed Dormancy	chemical inhibition, requires warm/cold stratification	**Seed Growing Requirements**	sow immediately in fall or sow pretreated seed in February at 2X depth of seed diameter
Seed Stratification	30 days at 15^o-20^o C, 90 days at 1^o-4^o C	**Wildlife Value**	primary host plant to rare butterfly, giant swallowtail
Seed Longevity (in soil seed bank)	>1 year	**Occurrence**	- rare, usually between 21-100 occurrences in Ontario - vulnerable in Canada
Germination Rate	16%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - only 27 populations in Ontario thought to be natural - largest population extends continuously for ~9.5 km along west shore of Point Pelee
Seed Pests	no data	**Silvicultural Concern**	establish group openings 1X tree canopy height or > downwind from parent tree to regenerate this species on suitable sites; monitoring and tending of regeneration required
Seedling Pests	desiccation	**Mature Tree Pests**	no data
Sprouting Ability	- sprouting occurs after storm damage - layering possible under artificial conditions	**Other**	seldom reaches tree height (> 6 m) in Ontario

Cucumber Tree[1]

Magnolia acuminata (L.) L.

Biological Features		Ecological Features	
Tree Longevity (years)	250, typically 80	**Site: Moisture Requirements**	moist to moderately moist sites
Fruiting Age (years)	30, peaks at 50+	**Site: Nutrient Requirements**	- deep, fertile, imperfect to well-drained humic soils - fine to coarse sands, loams
Seedcrop Periodicity (years)	- 4-5 - may be less frequent at the edge of its geographic range	**Climatic Range in Ontario**	- at northern limit of natural range - Deciduous Forest Region, specifically Regional Municipality of Haldimand-Norfolk, Region of Niagara along north shores of Lake Erie - successful grafting allows this species to be grown far north of natural range
Flower Type/Pollination Mechanism	perfect insects	**Genetics**	only Magnolia native to Canada
Seed Dispersal	September	**Seedbed Type**	mineral/humus mix
Dispersal Method	- birds - wind - water - gravity	**Shade Tolerance**	intermediate
Dispersal Distance	- vicinity of parent tree - greater distances when dispersed by birds, water	**Light Requirements**	seedlings: forest openings promote establishment
Seed Weight	moderate	**Shade Requirements**	seedlings: half shade during most of first summer
Seed Production	10-60 seeds/fruit	**Response to Release**	branches considerably in open stand situations
Seed Dormancy	biochemical inhibition, requires stratification for first-year germination	**Seed Growing Requirements**	sow stratified seed from February to May at depth of 2X seed diameter
Seed Stratification	210 days at 1^{o}-4^{o} C	**Wildlife Value**	wildlife use is low seeds: eaten by several species of birds, mammals twigs, leaves, buds: browsed by deer
Seed Longevity (in soil seed bank)	> 1 year	**Occurrence**	- endangered in Ontario; very rare, usually 6-20 occurrences in Ontario - endangered in Canada, threatened with imminent extirpation throughout Canadian range
Germination Rate	8-86%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - protect against indiscriminant logging, clearing; seek professional advice when dealing with native stands
Seed Pests	- rodents - birds - sensitive to freezing, desiccation	**Silvicultural Concern**	- to regenerate, establish openings ≥ 1X tree canopy height downwind of mature parent trees; monitoring, tending of regeneration required - low, moist openings in red/white pine plantation show potential for higher density sapling growth than natural conditions
Seedling Pests	frost	**Mature Tree Pests**	- sapsucker damage common - Nectria common (when tree is on unsuitable site)
Sprouting Ability	sprouts readily, regenerates best in clearcuts	**Other**	- very sensitive to ground fires, frost - represented by scattered individuals or small groups in even-aged stands - self-prunes well - not eaten by gypsy moth

[1] *Status Report prepared, February, 1983*

Dwarf Chinquapin Oak[1]

Quercus prinoides Willd.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	dry sites
Fruiting Age (years)	- no data - produces seed when barely 1 m high	**Site: Nutrient Requirements**	open, well-drained sand plains or dunes
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of its natural range - confined to four areas in Deciduous Forest Region (Site District 7E(2)) - specifically Pinery Provincial Park, Grand Bend, Port Franks; St. Williams Tree Nursery, Regional Municipality of Haldimand-Norfolk; near city of Brantford; near Town of Delhi
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with chinquapin, white oaks
Seed Dispersal	- early September to mid- or late-October - depends on timing of fall frost	**Seedbed Type**	no data
Dispersal Method	- gravity - rodents	**Shade Tolerance**	- intolerant - seedlings withstand moderate overstory or understory cover, become more intolerant with age
Dispersal Distance	- vicinity of parent tree - greater distances when dispersed by rodents	**Light Requirements**	increasingly important with age
Seed Weight	heavy	**Shade Requirements**	no data
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	none	**Seed Growing Requirements**	sow immediately in fall at depth 2X acorn diameter
Seed Stratification	none required	**Wildlife Value**	twigs leaves, buds, acorns: food for variety of wildlife species
Seed Longevity (in soil seed bank)	depends on moisture (not drop below 30-50%)	**Occurrence**	very rare, usually between 6-20 occurrences in Ontario
Germination Rate	high	**Conservation Concern**	- repeated browsing of new growth could limit species maintenance, potentially reduce population - southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- deer, rodents - wild turkey - acorn weevil	**Silvicultural Concern**	prescribed burning enhances regeneration, but must be protected from deer browsing
Seedling Pests	deer	**Mature Tree Pests**	- gypsy moth - oak wilt (usually kills tree within 2-4 years)
Sprouting Ability	vegetative reproduction readily achieved by cutting or burning	**Other**	in southern Ontario, occurs in communities or scattered individuals associated with best oak savanna habitats

[1] *Status Report prepared, January, 1992*

Dwarf Hackberry[1]

Celtis tenuifolia Nutt.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	dry to moist sites
Fruiting Age (years)	6-7	**Site: Nutrient Requirements**	- sandy to shallow soils over limestone (alvars) - pH optimum range 7.0-8.0
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- outside of northern part of its main area of distribution - Deciduous Forest Region, specifically Port Franks, Grand Bend Pinery area (Site District 7E(2)); Pelee Island, Point Pelee (Site District 7E(1)); shores of Lake Ontario, Hastings, Northumberland Counties (Site Districts 6E(13,15))
Flower Type/Pollination Mechanism	polygamo-monoecious wind	**Genetics**	may hybridize with hackberry (sometimes treated as a variety of it)
Seed Dispersal	late winter to early spring	**Seedbed Type**	humus
Dispersal Method	- gravity - birds - rodents	**Shade Tolerance**	intolerant
Dispersal Distance	- vicinity of parent tree - greater distances when dispersed by birds, rodents	**Light Requirements**	no strong preference seedlings: may require light for establishment
Seed Weight	moderate	**Shade Requirements**	no strong preference germination, seedlings: require some degree of shade
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	over-winter while fruits remain on branches	**Seed Growing Requirements**	sow untreated seeds in fall, or stratified seeds in spring
Seed Stratification	60-90 days at 5^{o}C, moist sand	**Wildlife Value**	seeds: food for wildlife leaves, twigs, buds: alternate food source for deer when preferred food scarce
Seed Longevity (in soil seed bank)	1-2 years	**Occurrence**	- very rare, usually between 6-20 occurrences in Ontario, considered biologically significant - vulnerable in Canada
Germination Rate	70-75%	**Conservation Concern**	- presence may be overlooked due to its resemblance to various other shrubs, small trees - habitat change associated with successional changes threatens species - further research required on biology, ecology of Ontario populations - southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- birds - rodents - desiccation	**Silvicultural Concern**	- periodic forest disturbance necessary to maintain species presence - stressed by allelopathic plants (walnuts, sumacs, and junipers) - prescribed burning maintains, expands suitable required open habitat, but species is susceptible to fire
Seedling Pests	- deer, rabbits - land snails - defoliators, leaf spot - root desiccation, sun scald, lack of nutrients, frost during first winter	**Mature Tree Pests**	browsed by deer, but not a preferred browse species when other food supplies exist
Sprouting Ability	- not significant in Ontario - stem suckers limited (<10%)	**Other**	seldom reaches tree height (> 6 m) in Ontario

[1] *Status Report prepared, August, 1994*

Eastern Cottonwood

Populus deltoides Bartram ex Marshall ssp. *deltoides*

Biological Features		Ecological Features	
Tree Longevity (years)	100, typically 60	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	5-10	**Site: Nutrient Requirements**	- soils range from muck to sand, silt, clay loams - well-drained - soils infertile (> 2 % organic matter) - pH optimum range 5.5 - 7.5
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of its natural range - Deciduous Forest Region - southern edge of Great Lakes-St. Lawrence Forest Region near Lake Ontario
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- range of environmental variables causes genetic differences in different populations - 3 subspecies of eastern cottonwood recognized - hybridizes freely with other poplars - crosses with *P. balsamifera* to produce *P. x Jackki* hybrids which are susceptible to Septoria canker
Seed Dispersal	June-July	**Seedbed Type**	mineral soils
Dispersal Method	- wind - water	**Shade Tolerance**	very intolerant
Dispersal Distance	- > 100 m by wind - great distances when transported by water	**Light Requirements**	seedlings: full sunlight for substantial part of each day required after first few weeks
Seed Weight	very light	**Shade Requirements**	germination: partial shade
Seed Production	48 million seeds/tree	**Response to Release**	- poor response - only those trees with well-developed crowns respond favorably
Seed Dormancy	none, germinates quickly	**Seed Growing Requirements**	sow in an acid, sand-peat mixture, covered with a thin layer of acid sand or peat to depth of 0.5 cm
Seed Stratification	none required	**Wildlife Value**	new growth: high in protein, minerals seedlings, twigs, leaves: provide browse for rabbits, deer (can recover from browsing damage) saplings, pole-sized trees: food, dam material for beaver
Seed Longevity (in soil seed bank)	2 weeks to 1 month	**Occurrence**	common
Germination Rate	90% (fresh seed)	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	no data	**Silvicultural Concern**	- prolonged flooding during growing season is damaging to new sprouts, established trees - competition from brush and weeds can easily eliminate 1-year-old seedlings
Seedling Pests	- deer, rabbits - borers, defoliators - Septoria leaf spot and canker - Cytospora canker - leaf spots, leaf rust	**Mature Tree Pests**	no data
Sprouting Ability	- sprouting from stumps < 25 years old satisfactory - root suckering uncommon	**Other**	- floods of short duration or during dormant season beneficial - very susceptible to fire (all ages) - slow growing for first 3 weeks, then fast growing

Eastern Flowering Dogwood

Cornus florida L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	typically 125	**Site: Moisture Requirements**	- moist sites - low tolerance to drought
Fruiting Age (years)	6	**Site: Nutrient Requirements**	- fertile soils - sand to muck soils - absent from poorly drained areas - pH optimum range 6.0-7.0
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- at northern limit of natural range - limited to Deciduous Forest Region
Flower Type/Pollination Mechanism	perfect no data	**Genetics**	not known to hybridize naturally
Seed Dispersal	October to November	**Seedbed Type**	mineral soils
Dispersal Method	- birds - mammals - gravity	**Shade Tolerance**	very tolerant
Dispersal Distance	- vicinity of parent tree - greater distances if transported by birds or mammals	**Light Requirements**	seedling: intermediate light intensity provides advantage to growth
Seed Weight	moderate	**Shade Requirements**	germination: only in shade seedlings: requires shade from hot afternoon sun
Seed Production	185kg/m^2 of basal area	**Response to Release**	- flowers more - larger openings result in greater phenolic production in individual trees
Seed Dormancy	biochemical inhibition causes a 1-2 year dormancy	**Seed Growing Requirements**	sow stratified seed in fall to depth 2X seed diameter
Seed Stratification	- clean fleshly fruit immediately - 120 days at 5^o C	**Wildlife Value**	nectar: food source for butterfly species seed: consumed by over 36 species of birds, a variety of mammals (squirrels and black bears) leaves, twigs: browsed by deer, rabbits
Seed Longevity (in soil seed bank)	> 2 years	**Occurrence**	- uncommon to locally common, at present, demonstrably secure in Ontario
Germination Rate	high	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - dogwood anthracnose has recently been confirmed in southern Ontario; may seriously threaten this species
Seed Pests	- mammals - birds	**Silvicultural Concern**	dogwood anthracnose has been reported as most severe in partial cuts and least severe in clearcuts
Seedling Pests	- deer, rabbits - defoliators, borers - leaf spots - sunscald - desiccation - freezing	**Mature Tree Pests**	- anthracnose - root knot nematode
Sprouting Ability	- sprouts best when cut late winter, increased sprout height with increased stump diameter - layers extensively	**Other**	- readily damaged by fire, flooding - seldom reaches tree height (> 6 m) in Ontario

Eastern Hemlock

Tsuga canadensis (L.) Carrière

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	988, typically 400	**Site: Moisture Requirements**	- wide range of sites - dry sites in southern Ontario - moist to very moist with good drainage
Fruiting Age (years)	15-30, later if suppressed	**Site: Nutrient Requirements**	- shallow loam to silty loam - often over granite gneiss, slate bedrock - seedlings tolerate shallow soils, coniferous litter - pH optimum range 5.0-7.0
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- at northern limit of its natural range - all of Great Lakes-St. Lawrence Region - scattered throughout Deciduous Forest Region, specifically Site Region 7E (3,4) - absent in Boreal Forest- Barren, Boreal Forest Regions
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	genetic variation in physiological, morphological characteristics associated with locality
Seed Dispersal	October to November	**Seedbed Type**	- mineral soil - burned duff - decaying wood
Dispersal Method	- wind - squirrels	**Shade Tolerance**	very tolerant
Dispersal Distance	- tree height - 30-60 m - the more dominant the species is in canopy, more apt to be found in seedling layer	**Light Requirements**	- species can survive as little as 5% full sunlight - unstratified seed: must be exposed to light to break partial dormancy - seedlings: found in small gaps, gap edges with decreasing numbers found as gap-size increases
Seed Weight	light, more southern trees have heavier seeds	**Shade Requirements**	germination: partial shade
Seed Production	no data	**Response to Release**	- responds in both height, diameter growth - excessive release results in reduced growth, mortality
Seed Dormancy	biochemical inhibition: requires stratification	**Seed Growing Requirements**	sow seeds on damp soil in spring
Seed Stratification	10 weeks at 0^{o} C	**Wildlife Value**	- excellent winter shelter, bedding for deer - cover for ruffed grouse, wild turkey, owls, other animals - food (browse)
Seed Longevity (in soil seed bank)	1 year on forest floor	**Occurrence**	was once more common as old-growth (presettlement)
Germination Rate	- 10-65% - commonly < 25%	**Conservation Concern**	older stands are rare, should be protected
Seed Pests	- mice, voles, squirrels, other rodents - moulds, particularly *Botrytis* spp. - Desiccation	**Silvicultural Concern**	- difficult to regenerate naturally due to its specific requirements, short seed dispersal distance - should be considered as residual in tolerant hardwood stands where it occurs as scattered stems - can be severely damaged, regeneration limited during years of high deer population - see Section 6.7
Seedling Pests	- browsing by deer (seedlings preferred), hares, rabbits - hemlock looper - desiccation	**Mature Tree Pests**	wooly adelgid causes major concerns; throughout NE states old-growth hemlock has been lost; managers should be observant for early signs of this pest in southern Ontario
Sprouting Ability	very rare, layering only	**Other**	- susceptible to windthrow - seedling growth slow

Eastern Red Cedar

Juniperus virginiana L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	300, typically 150	**Site: Moisture Requirements**	moist, well-drained alluvial sites
Fruiting Age (years)	10, more typically 25	**Site: Nutrient Requirements**	- wide variety of soils from dry, rock outcroppings to wet swampy lands - sandy soils - prefers acidic soils, not particularly tolerant of high pH levels
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- at northern limit of natural range - found in Deciduous Forest Region - Great Lakes-St. Lawrence Forest Region as far north as Georgian Bay
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- displays great diversity in phenotypic characteristics - no recognized hybrids
Seed Dispersal	February to March	**Seedbed Type**	mineral soils, slightly acidic
Dispersal Method	- wind - birds	**Shade Tolerance**	intolerant
Dispersal Distance	- < 20 m when by wind - 290 m by birds	**Light Requirements**	sun-adapted
Seed Weight	moderate	**Shade Requirements**	no data
Seed Production	1-4 seeds/cone	**Response to Release**	no data
Seed Dormancy	slight biochemical inhibition; seedcoat impermeability	**Seed Growing Requirements**	- collect seeds in fall, broadcast, cover with 6 mm soil or sand - sow stratified seed in spring
Seed Stratification	artificial: soak seeds for 96 h in 10,000 ppm citric acid followed by 36 days at 20^{o} C then 70 days at 3^{o} -5^{o} C	**Wildlife Value**	- provides good nesting, roosting cover for birds - seeds are food source for birds, many mammals - thickets provide good escape cover for deer - boughs provide emergency food for deer, but not preferred
Seed Longevity (in soil seed bank)	~ 1 year	**Occurrence**	uncommon
Germination Rate	averages 10%, improves to 40% if seeds pass through gut	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- rabbits, foxes, raccoons, skunks, opossums, coyotes - waxwings, bobwhite quail, ruffed grouse, pheasant, wild turkey	**Silvicultural Concern**	presence of red cedar infected with cedar apple rust presents problems to apple growers
Seedling Pests	- rabbits, mice - nematodes, grubs - cedar apple rust - frost-heaving - winter injury (of foliage)	**Mature Tree Pests**	- bagworms - spruce spider mites - cedar apple rust
Sprouting Ability	none	**Other**	highly susceptible to fire

Eastern White Cedar

Thuja occidentalis L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	>1,000 (on Niagara Escarpment), typically 300	**Site: Moisture Requirements**	- wide range of sites - grows on very wet to drought prone areas - poor growth on extreme wet, dry sites - more seedlings found on microsites with drier conditions (numerous hummocks)
Fruiting Age (years)	6, peaks at 75	**Site: Nutrient Requirements**	- wide range of organic, mineral soils, bedrock - moderately to well-decomposed organic soils - pH optimum range 6.0 - 8.0
Seedcrop Periodicity (years)	2-5	**Climatic Range in Ontario**	- Boreal Forest Region except all of Site Region 1E, eastern portion of 2E, western portion of 2W - most of Great Lakes-St. Lawrence Region - local relict populations in Deciduous Forest Region, specifically 7E (4) - absent in parts of Counties of Essex, Elgin, Haldimand-Norfolk, Kent, Lambton
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- morphologically similar throughout its range, however significant genetic variation exists - growth patterns are evident from different latitude and topographic locations
Seed Dispersal	September	**Seedbed Type**	- decayed wood - mineral soil - humus - sphagnum mosses - burned organic soils
Dispersal Method	- wind - squirrel cone caches	**Shade Tolerance**	very tolerant (vegetative reproduction) to intermediate (seedling)
Dispersal Distance	45-60 m	**Light Requirements**	seedlings: ample light needed for continued development
Seed Weight	light	**Shade Requirements**	germination: 50% shade reduces losses from drought, herbaceous competition
Seed Production	- 9 l cones/tree - 60,000-260,000 seeds/tree	**Response to Release**	- responds well at all ages - depends on site quality, residual stand density, stand age
Seed Dormancy	none to slight (biochemical inhibition)	**Seed Growing Requirements**	sow seeds on damp soil in fall
Seed Stratification	21-30 days at 2^o-5^o C	**Wildlife Value**	- winter shelter, browse for deer - food source for porcupine, snowshoe hare, red squirrel - nesting sites, cover for bird species - bark provides nesting material for squirrels
Seed Longevity (in soil seed bank)	~1 year on forest floor	**Occurrence**	common
Germination Rate	35-60%	**Conservation Concern**	- old-growth cedar stands are rare, and should be considered for protection - cedar stands (especially swamps) often provide habitat for rare plant species, including a variety of orchids
Seed Pests	- red squirrels - birds	**Silvicultural Concern**	see Section 6.6
Seedling Pests	- deer browsing (particularly planted stock) - girdling by small rodents - cedar leaf miner - smothering by sphagnum moss, logging slash - drought - foliage blight	**Mature Tree Pests**	- trees can sustain browsing below 2.5 m - trees under 2 m high are eliminated by deer in wintering areas
Sprouting Ability	layering (in swamps) - primary	**Other**	- seedling growth slow under forest conditions - slow growing

Eastern White Pine

Pinus strobus L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	450, typically 200	**Site: Moisture Requirements**	fresh to moderately fresh sites
Fruiting Age (years)	5-10, peaks at >20	**Site: Nutrient Requirements**	- soils medium in fertility - well-drained, sandy and gravelly-loams to shallow soil of all textures; organic soils, bedrock; poor growth on calcareous soils - pH optimum range 4.7-7.3
Seedcrop Periodicity (years)	3-5	**Climatic Range in Ontario**	- at northern part of its range - southern most portion of Boreal Forest Region - all of Great Lakes-St. Lawrence Region - scattered in Deciduous Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	stand to stand genetic variation
Seed Dispersal	August-September	**Seedbed Type**	- mineral soil (moisture content is critical factor) - pioneer mosses - burned duff
Dispersal Method	- wind - squirrels	**Shade Tolerance**	intermediate
Dispersal Distance	- 60 m within stand - 210 m in the open	**Light Requirements**	germination: 8-16 hrs/day seedlings: ≥ 20 % full sunlight; need 50 % for maximum growth
Seed Weight	light	**Shade Requirements**	germination, seedlings: partial shade increases germination rate, seedling growth
Seed Production	1.8 hectolitres cones/ tree	**Response to Release**	- depends on strength of competition , how long white pine has been subordinate - declines proportionately with increasing age, decreasing crown length
Seed Dormancy	biochemical inhibition: requires stratification	**Seed Growing Requirements**	sow seeds in February; cover with soil to depth of 2 X seed diameter
Seed Stratification	artificial: 30 to 60 days at 1 - 5^{o}C	**Wildlife Value**	- seeds: food for songbirds, small mammals; bark, foliage: food for mammals - winter cover - supercanopy trees for roosting, raptor nests, etc.
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate (%)	60-90	**Conservation Concern**	old-growth stands are rare, should be protected
Seed Pests	- squirrels, mice - white pine cone borer - desiccation	**Silvicultural Concern**	- needs some shading during early years to minimize white pine weevil damage to leaders - do not manage for white pine in high white pine blister rust risk areas (see Figure 3 on p. 4 of *White Pine Blister Rust & White Pine Weevil Management Guidelines,* OMNR 1990) and/or microsites with conditions that are conducive to white pine blister rust infection (e.g., lower valley slopes) - see Section 6.5
Seedling Pests	- damaged by deer only if left unprotected, shaded - mice (preferred over other species in old field situation) - pales weevil - white pine blister rust - Armillaria root disease	**Mature Tree Pests**	- very susceptible to juglone poisoning by walnut - damaged by root rot; white pine blister rust; white pine weevil; deer browsing; ice; snow - susceptible to pine shoot beetle a non-native insect species that threatens Scotch pine and native pine in southwestern Ontario
Sprouting Ability	none	**Other**	- early growth slow, rapid for open grown dominant trees - bark of older trees highly fire resistant

Gray Birch

Betula populifolia Marshall

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	typically 50	**Site: Moisture Requirements**	wet or dry sites
Fruiting Age (years)	8-15	**Site: Nutrient Requirements**	- sandy or gravelly soils - trees do well in poor, almost sterile soils
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of natural range - limited to Great Lakes-St. Lawrence Region bordering St. Lawrence River, northeastern shoreline of Lake Ontario (Site Districts 6E(9, 10,11,12,15))
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with white birch
Seed Dispersal	October to throughout winter	**Seedbed Type**	mineral soils (heavy duff layer will inhibit establishment) humus (exposed peat)
Dispersal Method	- wind (dispersal over snow can occur) - water	**Shade Tolerance**	intolerant
Dispersal Distance	considerable distance	**Light Requirements**	germination: full sunlight necessary
Seed Weight	light	**Shade Requirements**	seedlings: require shade for 2-3 months in summer
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	needs exposure to light	**Seed Growing Requirements**	sow after collection in late summer or fall, or sow seed that has been prechilled for 4-8 weeks in spring
Seed Stratification	90 days of 8+ hours sunlight	**Wildlife Value**	catkins, seed, buds: food for variety of wildlife species provides wildlife cover when in hedgerows
Seed Longevity (in soil seed bank)		**Occurrence**	common
Germination Rate	- 64 % - usually greater in years of high seed production	**Conservation Concern**	no data
Seed Pests	- squirrels, chipmunks, mice, voles - ruffed grouse	**Silvicultural Concern**	no data
Seedling Pests	- deer - birds	**Mature Tree Pests**	no data
Sprouting Ability	sprouts moderately	**Other**	responds well to browsing with new growth from dormant buds

Honey Locust[1]

Gleditsia triacanthos L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	125, typically 120	**Site: Moisture Requirements**	- dry-moist sites - very resistant to drought
Fruiting Age (years)	10, peaks between 25-75	**Site: Nutrient Requirements**	- fertile soils - roots respond to fertilization of N+K+P or to N alone - pH optimum range 6.0-8.0 - growth poor on gravelly or heavy clay soils
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- near northern limit of natural range - limited to Essex , Kent, Elgin counties, Regional Municipality of Niagara in Deciduous Forest Region (Site District 7E(1)) - frequently planted, naturalizes outside its range
Flower Type/Pollination Mechanism	polygamo-dioecious insects	**Genetics**	- wide genetic variations - numerous cultivars have been developed
Seed Dispersal	October to March	**Seedbed Type**	humus/mineral mix
Dispersal Method	livestock, other mammals (feces) birds (feces) wind	**Shade Tolerance**	intolerant
Dispersal Distance	- limited - great distances when transported by wind across crusted snow	**Light Requirements**	germination, seedlings: light required for establishment saplings, pole trees: light required for survival, optimum development
Seed Weight	light	**Shade Requirements**	none
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	physical properties of seedcoat - overcome by scarification	**Seed Growing Requirements**	sow pretreated seeds in February to depth 2X seed diameter
Seed Stratification	pour boiling water onto seeds, letting water, seeds cool for 24 hours or soaking in concentrated sulfuric acid for 1 hour	**Wildlife Value**	fruit, seeds: valuable source of nutrients (beans contain 12-13% protein; pods contain 42% carbohydrates) bark: food for rabbits
Seed Longevity (in soil seed bank)	several years	**Occurrence**	very rare, usually between 6-20 occurrences in Ontario
Germination Rate	high, increases with artificial seed scarification or naturally by passing through animal's digestive tract	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - scarce in natural state - known natural stands on Erie Islands, Lake Erie shoreline should be given priority, protection from indiscriminant forest clearing, agricultural encroachment, etc.
Seed Pests	- mammals - birds - bruchid weevil	**Silvicultural Concern**	- where possible, eliminate or reduce shade, protect from browsing - to regenerate, establish openings 1X canopy tree height in diameter or > and located downwind from mature parent trees; monitor regeneration
Seedling Pests	- rabbits - defoliators, twig girdler - sensitive to air pollution (including sulfur dioxide)	**Mature Tree Pests**	- heart rot - root decay
Sprouting Ability	sprouts, suckers readily	**Other**	- good windbreak species - highly resistant to gypsy moth - moderately fast growing

[1] *Status Report prepared, April, 1995*

Ironwood

Ostrya virginiana (Miller) K. Koch

Biological Features		Ecological Features	
Tree Longevity (years)	at least 140, usually much less	**Site: Moisture Requirements**	moist, moderately dry sites
Fruiting Age (years)	25	**Site: Nutrient Requirements**	- loam, shallow soils over limestone - pH optimum range 4.2-7.6
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - southern edge of Boreal Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	no variety in Ontario
Seed Dispersal	September to October	**Seedbed Type**	no preference
Dispersal Method	- wind - birds - rodents	**Shade Tolerance**	tolerant
Dispersal Distance	no data	**Light Requirements**	no data
Seed Weight	light	**Shade Requirements**	reproduces well under full shade
Seed Production	124,000 seeds /ha	**Response to Release**	advance reproduction aggressive when released by overstory cutting
Seed Dormancy	biochemical inhibition requires warm/cold stratification	**Seed Growing Requirements**	collect when colour changes to yellowish-brown; in fall, sow untreated seeds to depth 2X seed diameter (0.6 cm); in spring, sow pretreated seeds, keep moist until emergence complete
Seed Stratification	60 days at 20°-30° C followed by 140 days at 0°-5° C	**Wildlife Value**	buds: food source for grouse seeds: provides limited food supply to wildlife leaves, twigs, buds: browsed only incidentally by deer
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	27-65%	**Conservation Concern**	no data
Seed Pests	birds	**Silvicultural Concern**	once considered a weed tree; OMNR tree-markers may previously have marked this species so that it was entirely removed from some stands; now, certified tree-markers are encouraged to consider forest biodiversity values and leave a representative number of stems of this species
Seedling Pests	- deer, beaver - hop hornbeam anthracnose	**Mature Tree Pests**	- trunk, butt rots - Armillaria root disease in saplings
Sprouting Ability	- stump sprouting .common on cut, burned, injured trees - sprouting increases with stump height	**Other**	- slow to medium growth rate - resists wind, snow, ice damage

Jack Pine

Pinus banksiana Lamb.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	230, typically 60-80	**Site: Moisture Requirements**	dry sites
Fruiting Age (years)	5-10 under open-grown condition, peaks at 70-80	**Site: Nutrient Requirements**	- best on well-drained sandy loams - thin soils over granite, limestone - pH optimum range 4.5-7.0
Seedcrop Periodicity (years)	1-4	**Climatic Range in Ontario**	- Boreal Forest and Great Lakes-St. Lawrence Forest Regions except Site Region 6E - generally limited to plantations in southern Ontario (Site Regions 6E, 7E)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	various environments over wide range predispose genetic differences
Seed Dispersal	- all year - serotinous cones - require very hot, dry weather (27^{o}C), fire or very cold winter temperatures	**Seedbed Type**	- mineral soil - burned duff
Dispersal Method	- wind - squirrel cone caches	**Shade Tolerance**	intolerant
Dispersal Distance	- 2X tree height - 40-60m	**Light Requirements**	seedlings: full sunlight
Seed Weight	light	**Shade Requirements**	germination: on dry sites some shade to prevent desiccation of seeds
Seed Production	300-500 cones/tree	**Response to Release**	improves growth, development
Seed Dormancy	none to slight (biochemical inhibition)	**Seed Growing Requirements**	sow seeds in spring
Seed Stratification	14 days of cold temperatures	**Wildlife Value**	- homogeneous stands, > 32 ha, 7-20 years old are preferred breeding sites for rare Kirtland's warbler - food, shelter for wild game species including snowshoe hare, deer
Seed Longevity (in soil seed bank)	5 - 10 years	**Occurrence**	- common north of Canadian Shield - natural stands rare in southern Ontario, only occurring on rock barrens, alvar sites
Germination Rate	70 to 85 %,	**Conservation Concern**	no data
Seed Pests	- mammals (red squirrels, other rodents) - birds - insects	**Silvicultural Concern**	plantations established in southern Ontario should be converted to vegetation cover types that would naturally occur on these sites
Seedling Pests	- meadow voles cause damage, mortality in young stands - insects - drought - Armillaria root disease - needle rust - Sirococcus shoot blight - Scleroderris canker - sweetfern blister rust, Commandra blister rust - eastern, western gall rust	**Mature Tree Pests**	- porcupine can severely damage older stands - susceptible to pine shoot beetle a non-native insect species that threatens Scotch pine and native pine in southwestern Ontario
Sprouting Ability	none	**Other**	- young especially susceptible to early spring fires - fast growing when young

Kentucky Coffee-tree[1]

Gymnocladus dioicus (L.) K. Koch

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 90	**Site: Moisture Requirements**	moist to wet sites
Fruiting Age (years)	15-20	**Site: Nutrient Requirements**	- prefers fertile loam - shallow soils over limestone
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of natural range - Deciduous Forest Region, specifically Essex, Lambton and Middlesex counties, islands in western basin of Lake Erie
Flower Type/Pollination Mechanism	dioecious insects	**Genetics**	only member of its genus occurring in North America
Seed Dispersal	September to late winter or early spring	**Seedbed Type**	no data
Dispersal Method	water	**Shade Tolerance**	intolerant
Dispersal Distance	variable	**Light Requirements**	germination: unable to regenerate under own shade vegetative regeneration: light from clearings required
Seed Weight	moderate	**Shade Requirements**	none
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	physical properties of seedcoat - overcome by scarification	**Seed Growing Requirements**	sow pretreated seeds in spring, covering with 2.5 cm firm soil
Seed Stratification	soak seeds in water for 24 hours, then soak in concentrated sulfuric acid for ~150 minutes	**Wildlife Value**	none
Seed Longevity (in soil seed bank)	> 2 years	**Occurrence**	- threatened in Ontario - very rare, usually between 6-20 occurrences in Ontario - threatened in Canada
Germination Rate	86% (treated)	**Conservation Concern**	- requires protection from agricultural drainage, land clearing since found only as scattered individuals or isolated stands - southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	no data	**Silvicultural Concern**	- only 1 population reproduces by seed in Ontario, this area should be considered critical habitat - if forest restoration is a forest management objective, planting seedlings of this species into openings within forest stands on appropriate sites will be required - such introductions should occur only under guidance of a recovery plan for the species
Seedling Pests	no data	**Mature Tree Pests**	no data
Sprouting Ability	- suckers from roots readily, is main form of reproduction in Ontario - stress or cutting trees not necessary to induce root suckering	**Other**	

[1] *Status Report prepared, January, 1992*

Large-tooth Aspen

Populus grandidentata Michx.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 100, typically 70	**Site: Moisture Requirements**	moist to fresh sites
Fruiting Age (years)	10-20	**Site: Nutrient Requirements**	- prefers fertile, sand, loamy sand, light, sandy-loam - pH optimum range 4.8-6.5
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - southern fringe of Boreal Forest Region
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- 4 hybrids are recognized - natural hybrids of large-tooth and quaking aspen occur in nature infrequently (due to different flowering times)
Seed Dispersal	May to June	**Seedbed Type**	mineral soils
Dispersal Method	wind	**Shade Tolerance**	very intolerant
Dispersal Distance	several kilometers	**Light Requirements**	required at all life stages
Seed Weight	very light	**Shade Requirements**	none
Seed Production	> 1.5 million seeds/tree	**Response to Release**	responds well to thinning
Seed Dormancy	none	**Seed Growing Requirements**	do not cover seeds or press into soil; keep moist for first month after germination
Seed Stratification	none required	**Wildlife Value**	suckers, sprouts: highly preferred browse by deer, moose buds, leaves: source of food for Ruffed Grouse bark, leaves, twigs, branches: food, construction material for beaver
Seed Longevity (in soil seed bank)	2-3 weeks	**Occurrence**	common
Germination Rate	> 80% (laboratory conditions)	**Conservation Concern**	none
Seed Pests		**Silvicultural Concern**	competition from brush and weeds can easily eliminate 1-year-old seedlings
Seedling Pests	- do not commonly occur in nature - deer, hare, beaver - forest tent caterpillar - Venturia leaf and shoot blight - Armillaria root disease in coppice stands - desiccation	**Mature Tree Pests**	beaver
Sprouting Ability	- root suckers readily up to 30 m from parent tree in open areas - stump, root collar sprouts are rare (late September harvesting produces most stump sprouts, compared to late August that produces fewest stump sprouts)	**Other**	- susceptible to fire damage, however suckering ability enables fire killed stands to rapidly re-vegetate - browsing provides beneficial thinning in younger stands

Mountain Maple

Acer spicatum Lam.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	30	**Site: Nutrient Requirements**	fertile, well-drained soils
Seedcrop Periodicity (years)	3-7	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - southern half of Boreal Forest Region (excluding Site Regions 1E,northern halves of 2E, 2W)
Flower Type/Pollination Mechanism	polygamo-monoecious no data	**Genetics**	no data
Seed Dispersal	October to December	**Seedbed Type**	muck
Dispersal Method	wind	**Shade Tolerance**	tolerant
Dispersal Distance	no data	**Light Requirements**	all life stages: limited
Seed Weight	light	**Shade Requirements**	all life stages: require shade, seldom found in open
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	no data	**Seed Growing Requirements**	no data
Seed Stratification	no data	**Wildlife Value**	buds, flowers, seeds: food source for variety of birds, small mammals twigs, foliage: food source for deer, porcupine
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	34% (treated)	**Conservation Concern**	none
Seed Pests	no data	**Silvicultural Concern**	no data
Seedling Pests	- anthracnose - leaf spot	**Mature Tree Pests**	no data
Sprouting Ability	- stump sprouts readily; stump height does not affect longevity of sprouts - layers often	**Other**	seldom reaches tree height (> 6 m) in Ontario

Northern Pin Oak

Quercus ellipsoidalis E. J. Hill

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	- dry, well-drained sites - drought tolerant
Fruiting Age (years)	15-20	**Site: Nutrient Requirements**	- prefers sandy soils - also grows on moraine, clay, stony-loam
Seedcrop Periodicity (years)	3-5	**Climatic Range in Ontario**	- Deciduous Forest Region, specifically, north of Long Point - Great Lakes-St. Lawrence Forest Region; a dominant tree species in a stand near Rainy River (Site Region 5S) - minor geographic regions in southern Ontario include: Norfolk sand plain, isolated locations within Haldimand clay plain, Horseshoe moraines
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with black oak
Seed Dispersal	late August to October	**Seedbed Type**	mineral soils
Dispersal Method	- gravity - rodents (squirrels) - birds	**Shade Tolerance**	intolerant
Dispersal Distance	- vicinity of parent tree - greater distances when transported by rodents or birds	**Light Requirements**	all life stages: very demanding of light
Seed Weight	moderate	**Shade Requirements**	germination: partial shade is beneficial for good germination
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	slight, requires cold stratification	**Seed Growing Requirements**	sow in fall, cover with firmed soil 2X seed diameter (0.6 cm) natural: undergoes prechilling through fall, germinates in spring
Seed Stratification	60-90 days at 0^{o}-2^{o} C	**Wildlife Value**	due to rare occurrence in Ontario, likely has limited wildlife value acorns: valuable food source for black bear, deer, squirrels, variety of birds twigs, foliage: food source for deer
Seed Longevity (in soil seed bank)	no data	**Occurrence**	rare in Ontario, usually between 21-100 occurrences
Germination Rate	95%	**Conservation Concern**	most populations in southern Ontario consist of <5 trees generally in poor health with largest population, near Brantford, being just over 100 trees
Seed Pests	weevil larvae	**Silvicultural Concern**	to regenerate, establish openings 1x canopy tree height in diameter or > in vicinity of mature, parent trees; monitor regeneration
Seedling Pests	anthracnose	**Mature Tree Pests**	no data
Sprouting Ability	sprouting a common means of reproduction	**Other**	- periodic disturbances are required in order to sustain its population - low intensity fire can enhance photosynthetic performance

Ohio Buckeye

Aesculus glabra Willd. var. *glabra*

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 80	**Site: Moisture Requirements**	- prefers moist sites - can survive on dry sites
Fruiting Age (years)	8	**Site: Nutrient Requirements**	sandy -loam, calcareous soils
Seedcrop Periodicity (years)	1+	**Climatic Range in Ontario**	- at northern limit of its natural range - Deciduous Forest Region (limited to Walpole Island in Lake St. Clair) - cultivated populations also known
Flower Type/Pollination Mechanism	polygamo-monoecious no data	**Genetics**	hybridize with the non-native ornamental horse chestnut
Seed Dispersal	September to late October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - rodents - water (occasionally)	**Shade Tolerance**	intermediate to tolerant
Dispersal Distance	- vicinity of parent tree - greater distances if transported by animal activity or water	**Light Requirements**	seedlings: prefers some light but can grow under some shade
Seed Weight	moderately heavy	**Shade Requirements**	none
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	in first year	**Seed Growing Requirements**	plant, mulch cured nuts in September to October or plant in spring as early as possible using stratified seed; sow seeds 2.5-5 cm deep, 7.6-10 cm apart natural: sow immediately
Seed Stratification	120 days at 15-25^{o}C	**Wildlife Value**	none seeds, young shoots: poisonous to many animals
Seed Longevity (in soil seed bank)	no data	**Occurrence**	extremely rare, usually 5 or fewer occurrences in Ontario
Germination Rate	76% (treated)	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - existing individual stems should be protected
Seed Pests	no data	**Silvicultural Concern**	encourage regeneration on suitable sites by locating openings in forest canopy that are ≥ 1X tree height and in vicinity of mature, parent trees; monitor regeneration
Seedling Pests	- leaf blotch, leaf scorch - frost	**Mature Tree Pests**	no data
Sprouting Ability	no data	**Other**	good self-pruner

Pawpaw[2]

Asimina triloba (L.) Dunal

Biological Features		**Ecological Features**	
Tree Longevity (years)	typically 5-60	**Site: Moisture Requirements**	moist to moderately moist sites
Fruiting Age (years)	5	**Site: Nutrient Requirements**	- fertile loam soils, rich in humus - usually clay , but may also grow in sand - seedlings require pH of 5.0-5.7
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of natural range - restricted to Deciduous Forest Region, specifically 35+ locations in Niagara Region, counties of Lake Erie, includes Haldimand-Norfolk, Elgin, Middlesex, Lambton, Kent, Essex - known to be artificially established outside its natural range, e.g., Dominion Aboretum and Botanic Garden, Ottawa
Flower Type/Pollination Mechanism	perfect insects	**Genetics**	no other genera in Canada
Seed Dispersal	September to early October	**Seedbed Type**	humus
Dispersal Method	- coyote, fox, opossum, raccoon - birds - water	**Shade Tolerance**	very tolerant (including seedling stage)
Dispersal Distance	variable	**Light Requirements**	seedlings; can grow in full sunlight if well-watered
Seed Weight	moderate	**Shade Requirements**	seedlings: require shade for soil moisture retention
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	biochemical inhibition, physical properties of seedcoat delay germination, require stratification	**Seed Growing Requirements**	sow untreated seeds in fall or pretreated seeds in February; cover with 1.5 - 2 cm soil
Seed Stratification	60-120 days at 5^{o} C	**Wildlife Value**	fruit: food for mammals, birds leaves: sole host of zebra swallowtail butterfly, a provincially endangered species currently known only as rare visitor to Ontario
Seed Longevity (in soil seed bank)	no data	**Occurrence**	rare in Ontario, usually between 21-100 occurrences in Ontario
Germination Rate	50-82%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - known stands should be protected - monitor for presence of zebra swallowtail butterfly (provincially endangered)
Seed Pests	raccoons, opossum, squirrels	**Silvicultural Concern**	clonal populations produce very little or no fruit
Seedling Pests	leaf spot	**Mature Tree Pests**	no data
Sprouting Ability	- root suckers common - layering (artificial propagation)	**Other**	- generally found singly or in small groups - seldom reaches tree height (> 6 m) in Ontario - fruit not always as flavorful in Ontario as in more southern parts of its range

[2] *Status Report prepared, February, 1994*

Pignut Hickory

Carya glabra **(**Miller) Sweet

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 300, typically 200	**Site: Moisture Requirements**	moist to dry sites
Fruiting Age (years)	30, peaks at 75-200	**Site: Nutrient Requirements**	- responds to increases in soil nitrogen - sand or clay soils
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- near northern limit of natural range - limited to southern edge of Deciduous Forest Region (Site Districts 7E(1,2,3,5)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- naturally hybridizes with other hickories - *Carya ovalis* has been treated as a variety of *C. glabra* and as an interspecific hybrid of *C. glabra* and *C. ovata*
Seed Dispersal	September to December	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - squirrels, chipmunks	**Shade Tolerance**	intolerant
Dispersal Distance	- vicinity of parent tree - greater distances when transported by squirrels, chipmunks	**Light Requirements**	no data
Seed Weight	moderately heavy	**Shade Requirements**	no data
Seed Production	no data	**Response to Release**	seldom form epicormic branches
Seed Dormancy	biochemical inhibition overcome naturally over winter or artificial stratification	**Seed Growing Requirements**	sow untreated seeds in fall, pretreated seeds in spring
Seed Stratification	30-150 days at 1^{o}-4^{o} C	**Wildlife Value**	flowers: food for wild turkey nuts: food for squirrels, wild turkey, several species of songbirds nuts, bark: food for foxes, rabbits, raccoons leaves, twigs, nuts: food for deer, chipmunks
Seed Longevity (in soil seed bank)	< 1year	**Occurrence**	rare in Ontario, usually between 21-100 occurrences in Ontario
Germination Rate	60% (treated)	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - existing stems should be protected from indiscriminant forest clearing - tree-markers should leave stems of this species as residuals
Seed Pests	- squirrels, chipmunks - hickory shuckworm can seriously reduce germination	**Silvicultural Concern**	to encourage regeneration, locate openings 1X canopy tree height in diameter near existing mature, seed-producing trees in forest stands on appropriate sites; monitor regeneration
Seedling Pests	- chipmunks, deer - hickory bark beetle - anthracnose - mildew	**Mature Tree Pests**	- 1 of several host species of twig girdler (*Oncideres cingulata*) that severely damages trees - gall-forming fungi - gall-producing insects - easily damaged by fire
Sprouting Ability	- sprouts from stumps readily (small stumps sprout more frequently than larger stumps) - suckers from roots more vigorous, numerous than stump sprouts	**Other**	seedling growth slow

Pin Oak

Quercus palustris Muenchh.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	150, typically 100	**Site: Moisture Requirements**	dry-moist sites
Fruiting Age (years)	15-20	**Site: Nutrient Requirements**	- low nutrient requirements - poorly-drained sand, sandy loam, clay soils - prefers acidic soils
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- near northern part of natural range - limited to Essex, Lincoln, Welland Counties in Deciduous Forest Region (site Districts 7E(1,3,5)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- existence of races or populations has been suggested - 5 hybrids are recognized but only hybridizes with black oak in Ontario
Seed Dispersal	September to early December	**Seedbed Type**	humus/mineral mix
Dispersal Method	- squirrels, mice - blue jay, woodpeckers - gravity	**Shade Tolerance**	intolerant
Dispersal Distance	- vicinity of parent tree - 1900 m if transported by blue jay	**Light Requirements**	seedlings: require light for development, growth, become more shade intolerant with age
Seed Weight	moderate	**Shade Requirements**	none
Seed Production	492,700 seeds/ha	**Response to Release**	- responds rapidly (height and diameter growth) to thinning - develops epicormic sprouts when pruned
Seed Dormancy	biochemical inhibition overcome with stratification	**Seed Growing Requirements**	sow in fall at a depth 2X acorn diameter
Seed Stratification	30-45 days at 0^{o}-5^{o} C	**Wildlife Value**	acorns: food for migratory ducks, other forest wildlife seedlings, leaves: browsed by deer
Seed Longevity (in soil seed bank)	1 year	**Occurrence**	rare in Ontario, usually between 21-100 occurrences
Germination Rate	68 % (treated)	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - existing stems should be protected from indiscriminant forest clearing - tree-markers should leave stems of this species as residuals
Seed Pests	- deer, squirrels, mice - blue jays, wild turkey, woodpeckers - acorn weevil	**Silvicultural Concern**	to encourage regeneration, locate openings 1X canopy tree height in diameter near existing mature, seed-producing trees in forest stands on appropriate sites; monitor regeneration
Seedling Pests	- deer - defoliators, wood borers - leaf blister, twig canker	**Mature Tree Pests**	- susceptible to leaf blister, shoot blight, twig canker fungi - may be injured or killed by intermittent growing season flooding over several consecutive years
Sprouting Ability	- sprouts from young stumps vigorously - young seedlings sprout readily if injured or physiologically damaged	**Other**	- especially susceptible to damage by fire - not self-pruning - fast growing, roots respond to fertilization alone

Pitch Pine

Pinus rigida Miller

Biological Features		Ecological Features	
Tree Longevity (years)	200	**Site: Moisture Requirements**	- wide range of moisture conditions - requires sufficient moisture for germination, seedling growth, otherwise suited to dry sites
Fruiting Age (years)	- 8-12 - 4-5 (if originates from stump sprouts)	**Site: Nutrient Requirements**	- usually restricted to less fertile soils; can grow on almost sterile soils - requires fixed nitrogen for optimum growth - prefers deep soils, but generally grows on shallow, sandy-gravelly soils - pH optimum range 3.5-5.1
Seedcrop Periodicity (years)	1-3	**Climatic Range in Ontario**	- at northern limit of its range - southern edge of Great Lakes-St. Lawrence Forest Region, in Site Districts 6E(10,11) - more specifically Leeds County, in a small, triangle-shaped area from Brockville to Gananoque to Elgin
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- genetically variable among individuals within populations - genetic variation in cold tolerance between populations separated by as little as 8 km - frequency of serotinous cones genetically controlled – varies between populations - no natural hybrids in Ontario
Seed Dispersal	November-April	**Seedbed Type**	mineral soils
Dispersal Method	- wind; fire assists cone opening, seed dispersal	**Shade Tolerance**	very intolerant
Dispersal Distance	within 90 m	**Light Requirements**	seedlings: grow more vigorously in full sunlight
Seed Weight	light	**Shade Requirements**	no data
Seed Production	<30-35 seeds/cone	**Response to Release**	epicormic branching
Seed Dormancy	- none to slight - fire and sufficient moisture increase chances of germination	**Seed Growing Requirements**	- collect cones while still green; in spring, press seeds into substrate with pH of 4.8 - germination from sowing more successful than direct seeding during drought years
Seed Stratification	none	**Wildlife Value**	- food source for deer, rabbits, mice etc. - preferred over other pines by porcupine
Seed Longevity (in soil seed bank)	<1 year	**Rarity**	rare to very rare (<50,000 trees in Ontario)
Germination Rate	52-94 %	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - Ontario populations rare, on decline, show reduced vigour; should be protected
Seed Pests	- squirrels, mice - warblers, grosbeaks, chickadees - cone borers - desiccation	**Silvicultural Concern**	- limited seeding, planting programs, coupled with fire, manual maintenance may be required to maintain declining populations - remove white pine, red oak, shrubs from pitch pine sites; they reduce ability of pitch pine to become established, maintain itself
Seedling Pests	- deer, porcupines, rabbits, mice - competition with grass, other seedlings, trees - seedlings <2 years old, very susceptible to drought	**Mature Tree Pests**	- more susceptible to pests in northern part of range - brown needle syndrome, canker, root rot
Sprouting Ability	- sprouts frequently at base if damaged or stem is killed - sprout survival improves when parent tree is 60-90 years old - develops new shoots from dormant buds on trunk - seedlings sprout after damage by browsing, fire	**Other**	- drought, fire resistant - requires site disturbance for regeneration

Pumpkin Ash

Fraxinus profunda Bush

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	wet to very wet sites
Fruiting Age (years)	10	**Site: Nutrient Requirements**	- mineral soils of slit loam to clay loam, often with surface layer of muck or shallow peat - grows more rapidly in well-drained soil
Seedcrop Periodicity (years)	no data	**Climatic Range in Ontario**	- recently identified in Canada - limited to several sites in Deciduous Forest Region (e.g., Rondeau Provincial Park)
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- considered to be true-breeding polyploid derivative of diploid red ash X tetraploid white ash - no race or hybrids reported
Seed Dispersal	October to December	**Seedbed Type**	mineral soils
Dispersal Method	- wind - water (possible)	**Shade Tolerance**	intermediate (becomes less tolerant with age)
Dispersal Distance	no data	**Light Requirements**	no data
Seed Weight	light	**Shade Requirements**	germination: shade may be beneficial seedlings; grow rapidly in moderate shade if not preempted by ground cover, dense overstory
Seed Production	not considered prolific seed producer	**Response to Release**	no data
Seed Dormancy	the first year	**Seed Growing Requirements**	sow untreated seed in fall; pretreated seeds in spring; cover with 0.6-0.8 cm of soil
Seed Stratification	60 days at 5^{o}C	**Wildlife Value**	seeds: food for Wood Ducks, many other birds leaves, twigs: browsed by deer
Seed Longevity (in soil seed bank)		**Occurrence**	very rare, usually between 6-20 occurrences in Ontario
Germination Rate	high	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - existing stems should be protected from indiscriminant forest clearing - tree-markers should leave stems of this species as residuals
Seed Pests	birds	**Silvicultural Concern**	to encourage regeneration, locate openings 1X canopy tree height in diameter near existing mature, seed-producing trees in forest stands on appropriate sites; monitor regeneration
Seedling Pests	deer	**Mature Tree Pests**	- deer browse young twigs, leaves - upper stem heart rot may be severe in over-mature trees
Sprouting Ability	sprouts readily from sapling, pole-size trees	**Other**	very susceptible to fire

Red Ash (Green Ash)[1]

Fraxinus pennsylvanica Marshall

BIOLOGICAL FEATURES		**ECOLOGICAL FEATURES**	
Tree Longevity (years)	typically > 65	**Site: Moisture Requirements**	- moist sites - common on land subject to flooding
Fruiting Age (years)	20	**Site: Nutrient Requirements**	- grows best on fertile soils - adapts to variable soil textures - pH optimum range 6.0-8.0
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - also southwestern tip of Site Region 3E in Boreal Forest Region
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	- 3 or more geographic ecotypes - artificial cross of red ash x velvet ash successful
Seed Dispersal	October to spring	**Seedbed Type**	humus/mineral mix
Dispersal Method	- wind - water (possible)	**Shade Tolerance**	tolerant
Dispersal Distance	- vicinity of parent tree - greater distances by wind	**Light Requirements**	prefers full sun
Seed Weight	light	**Shade Requirements**	germination: partial shade
Seed Production	no data	**Response to Release**	- good response, outgrows many competitors - little to no epicormic branching
Seed Dormancy	biochemical inhibition, physical properties of seedcoat in older seed result in greater degree of dormancy than in fresh seed	**Seed Growing Requirements**	sow seeds in fall; cover with about 1.2 cm of sand; keep moist
Seed Stratification	60 days at 20^{o}C then 60-150 days at 0^{o} to 5^{o}C	**Wildlife Value**	seeds: food for many game, non-game birds, mammals twigs, leaves: browsed by deer, rabbits
Seed Longevity (in soil seed bank)	several years	**Occurrence**	common
Germination Rate	no data	**Conservation Concern**	none
Seed Pests	- birds - small mammals	**Silvicultural Concern**	no data
Seedling Pests	- deer, rabbits - oystershell scale, ash borer - leaf spot - anthracnose	**Mature Tree Pests**	- leaf spot - root rot fungi
Sprouting Ability	sapling, pole-sized stumps sprout readily	**Other**	not usually a preferred browse species but will recover when browsed

[1] Red Ash and Green Ash are considered to be one-in-the-same species

Red Maple

Acer rubrum L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	150, typically 80	**Site: Moisture Requirements**	- wide range of conditions - dry to moist to wet sites - seedlings very tolerant of flooding
Fruiting Age (years)	4	**Site: Nutrient Requirements**	- deep, fertile soils - most soil types, textures including shallow soils over limestone with pH 4.0-7.5
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - uncommon, but present in Boreal Forest Region
Flower Type/Pollination Mechanism	polygamo-dioecious insects	**Genetics**	hybridizes with silver maple, intermediate forms often occur
Seed Dispersal	June to July	**Seedbed Type**	- wide variety of seedbeds - prefers mineral soil - burned duff - seedlings can tolerate coniferous litter
Dispersal Method	- wind - water	**Shade Tolerance**	tolerant
Dispersal Distance	100+ m	**Light Requirements**	germination: requires very little light , but dense overstory can depress first-year germination seedlings: survive well in small, large gaps; must be released from under closed canopy or many will die annually
Seed Weight	very light	**Shade Requirements**	seedlings: abundant in understory advance reproduction
Seed Production	10,000-1,000,000 seeds/tree	**Response to Release**	- responds rapidly to heavy release - early crop tree release of seedlings, sprouts feasible in young, even-aged stands - responds well to thinning - low susceptibility to epicormic sprouting
Seed Dormancy	none to slight	**Seed Growing Requirements**	sow immediately after seed dispersal, to depth of 2X seed diameter in sandy loam, keep moist, partially shaded
Seed Stratification	30-90 days at 0^{o}-5^{o} C	**Wildlife Value**	buds, seeds: food source for small mammals, variety of birds leaves, twigs: browsed by deer, hares, rabbits
Seed Longevity (in soil seed bank)	1-2 years	**Occurrence**	common
Germination Rate	85-91%	**Conservation Concern**	none
Seed Pests	- hares, chipmunks - birds	**Silvicultural Concern**	
Seedling Pests	- deer, hare, rabbits, chipmunks, mice, voles - defoliators, borers - anthracnose - bacterial leaf scorch - Venturia leaf blight - Verticillium wilt	**Mature Tree Pests**	- sapsucker damage, may lead to ringshake - low tolerance to browsing - heart rot fungi
Sprouting Ability	- stump sprouts vigorously if tree cut down or damaged by fire - number of stump sprouts increase with stump diameter to maximum of 23-30 cm, then decrease on larger stumps	**Other**	- very susceptible to damage by fire - possible inhibition by benzoic acid from black cherry - rapid growth during early life, but slows after pole stage

Red Mulberry [2]

Morus rubra L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	typically 125	**Site: Moisture Requirements**	- variety of moist sites - moderately tolerant of flooding
Fruiting Age (years)	10, peaks at 30-85	**Site: Nutrient Requirements**	no data
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- Deciduous Forest Region - found in 2 areas: between Lake Ontario and southern section of the Niagara Escarpment, near Lake Erie in Essex, Kent counties - in particular, Niagara Escarpment, Point Pelee, Fish Point, Pelee Island
Flower Type/Pollination Mechanism	dioecious; sometimes monoecious wind	**Genetics**	freely hybridizes with white mulberry, a native of China that has naturalized in U.S.A., Canada; subject to “genetic swamping”
Seed Dispersal	June to August	**Seedbed Type**	requires surface disturbance to expose mineral soil
Dispersal Method	- gravity - small mammals - birds	**Shade Tolerance**	tolerant
Dispersal Distance	- vicinity of parent tree - greater distances if transported by birds, mammals	**Light Requirements**	partial opening in canopy required for successful establishment
Seed Weight	light	**Shade Requirements**	germination: half-shade for first weeks after emergence
Seed Production	large crops	**Response to Release**	no data
Seed Dormancy	no data	**Seed Growing Requirements**	sow untreated seed immediately after collection in mid-summer to early fall or sow pretreated seeds in spring
Seed Stratification	not required	**Wildlife Value**	fruit: favoured food of birds, small mammals leaves: food source for herbivores seedlings: browsed by deer, other herbivores
Seed Longevity (in soil seed bank)	no data	**Occurrence**	- very rare in Ontario; confirmed in 10 locations (only 6 of which have more than 5 individuals each); total known population 123 individuals; only 1 population has evident of reproduction, with little successful regeneration - endangered in Canada; not common
Germination Rate	12-50%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - declining species occurrence due to loss of habitat, hybridization with white mulberry - a recovery plan has been prepared for this species
Seed Pests	- opossum, raccoon, squirrels - birds	**Silvicultural Concern**	- remove white mulberry (girdle or cut stump herbicide treatment) when within wind pollination range of red mulberry - white x red mulberry, intermediate hybrids species recognition difficult; seek advice of competent botanist
Seedling Pests	- deer, other herbivores - defoliators, borers - twig blight, leaf spots	**Mature Tree Pests**	- deer browsing; protect confirmed regeneration from browsing in high deer-density areas - susceptible to twig blight disease causing mortality
Sprouting Ability	sprouts prolifically from roots	**Other**	

[2] *COSEWIC Status report prepared in 1987 (Ambrose 1987) ; RENEW Recovery Plan in 1998 (Ambrose 1998)*

Red Oak

Quercus rubra L.

Biological Features		Ecological Features	
Tree Longevity (years)	400, typically 200	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	25, peaks after 50	**Site: Nutrient Requirements**	- relatively fertile sites - deep, well-drained loam to silty, clay-loam soils - common on rock barrens
Seedcrop Periodicity (years)	2-5	**Climatic Range in Ontario**	throughout Deciduous, Great Lakes-St. Lawrence Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with northern pin, black, Shumard oaks
Seed Dispersal	September to October	**Seedbed Type**	mineral soils
Dispersal Method	- gravity - squirrels, mice - blue jays	**Shade Tolerance**	- tolerant - becomes less tolerant with age
Dispersal Distance	- vicinity of parent tree - greater distances when transported by animals	**Light Requirements**	seedlings: best growth at 30% full sunlight
Seed Weight	moderate	**Shade Requirements**	germination: high in full shade
Seed Production	800-1600 acorns/tree	**Response to Release**	- responds well if released trees are in the codominant or above average intermediate crown classes - best response if release occurs in an even-aged stand younger than 30 years old - epicormic branching can be prolific in stands greater than 30 years of age
Seed Dormancy	biochemical inhibition prevents germination until following spring or early summer	**Seed Growing Requirements**	sow acorns in fall at depth 2X acorn diameter
Seed Stratification	30-45 days at 0^o-5^o C	**Wildlife Value**	provides 1 of the best sources of mast for wildlife acorns: valuable food for forest wildlife, but less preferred than white oak; in non-bumper seed years red oak acorns are predated seedlings, leaves, twigs: browsed by deer, makes good recovery 1 of larval food-plants of Edwards Hairstreak butterfly, a rare species in Ontario
Seed Longevity (in soil seed bank)	1 year	**Occurrence**	common
Germination Rate	84%	**Conservation Concern**	none
Seed Pests	- deer, squirrels, small rodents - wild turkey, blue jays, other birds - nut weevils	**Silvicultural Concern**	tree-markers should retain numerous high acorn producing oak trees (DBH = 40-65 cm)
Seedling Pests	- deer - gypsy moth, Asiatic oak weevil - anthracnose, leaf blister	**Mature Tree Pests**	Armillaria
Sprouting Ability	sprouts prolifically after cutting, fire	**Other**	- prescribed burns kill small seedlings, but larger stems will resprout - moderate to fast growing

Red Pine

Pinus resinosa Sol. ex Aiton

Biological Features		Ecological Features	
Tree Longevity (years)	>300, typically 200	**Site: Moisture Requirements**	dry sites
Fruiting Age (years)	- 15-25 in open-grown trees - 50-60 for trees in closed stands - peaks between 50-150	**Site: Nutrient Requirements**	- moderate-low fertility - well to moderately-well drained sandy soils - poor growth on calcareous soils - pH optimum range 4.5-6.0
Seedcrop Periodicity (years)	3-7	**Climatic Range in Ontario**	- Boreal Forest Region except for Site Regions1E, 2E, 2W - Great Lakes-St. Lawrence Forest Region - not found naturally in southwestern counties of Brant, Haldimand-Norfolk, Oxford, Middlesex, Elgin, Kent, Essex, south portion of Lambton - absent in Deciduous Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- uniform morphologically - little variation (the Pettawawa National Forest Institute maintains an archive of red pine mutations)
Seed Dispersal	- begins with cone ripening, continues to next summer - most seed falls during warm, fall days (October-November)	**Seedbed Type**	- mineral soil - burned duff - pioneer mosses
Dispersal Method	- wind - squirrel cone caches	**Shade Tolerance**	intolerant (more intolerant with age or as environment becomes warmer)
Dispersal Distance	- 12 m average - 275 m maximum	**Light Requirements**	seedlings: minimum 35% full sunlight; maximum growth of 5-year-old seedling at 65 -100% sunlight
Seed Weight	light	**Shade Requirements**	germination: partial shade (full sunlight inhibits seed germination)
Seed Production	18 litres cones/ tree	**Response to Release**	- best when thinned periodically from age 32 - shows good response even after suppression for 200 years
Seed Dormancy	none to slight (biochemical inhibition): may require short period of stratification	**Seed Growing Requirements**	sow seeds in fall or spring; cover seed with 0.7 cm of soil
Seed Stratification	artificial: 14-21 days	**Wildlife Value**	cover, nesting sites, food
Seed Longevity (in soil seed bank)	1-3 years on forest floor	**Occurrence**	common
Germination Rate	75-85%	**Conservation Concern**	old-growth stands are rare and should be protected
Seed Pests	- squirrels - songbirds	**Silvicultural Concern**	- plantations established in southern Ontario should be thinned to promote restoration to more natural, native hardwood forest cover - see Section 6.5
Seedling Pests	- deer, rabbits - pine false webworm - Scleroderris canker - needle cast, needle rust - Diplodia tip blight - Sirococcus tip blight - Armillaria root disease - Annosus root rot	**Mature Tree Pests**	susceptible to pine shoot beetle, a non-native insect species that threatens Scotch pine and native pine in southwestern Ontario
Sprouting Ability	- none in southern Ontario - layering common near tree-line	**Other**	- excellent self-pruner - larch sawfly drastically reduced this species in Ontario 80-90 years ago - saplings girdled by porcupine - growth slow, climatic conditions limit growth

Red Spruce

Picea rubens Sarg.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	400, typically 200	**Site: Moisture Requirements**	- occurs on dry to moist upland sites and wet organic sites - requires moisture and cool climate - requires sufficient moisture for germination
Fruiting Age (years)	35-40	**Site: Nutrient Requirements**	- grows on acid sandy loams; shallow rocky soils; shallow organic soils - pH range 4.0-5.5
Seedcrop Periodicity (years)	3-8	**Climatic Range in Ontario**	- restricted distribution in Ontario - found primarily in Site Region 5E (within Algonquin Park) with scattered occurrences reported in Site Region 6E (eastern Ontario)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- genetically variable among individuals within populations - genetic variation in cold tolerance between populations separated by as little as 8 km
Seed Dispersal	October to March	**Seedbed Type**	- mineral soils - humus - rotting wood
Dispersal Method	wind	**Shade Tolerance**	tolerant to very tolerant
Dispersal Distance	within 100m	**Light Requirements**	germination: best at 10% light but requires 50% light for optimal growth of established seedlings
Seed Weight	light	**Shade Requirements**	heavy mortality of seedlings grown in open if temperatures reach 46° C, even briefly
Seed Production	1150 cones/tree	**Response to Release**	responds to release after 145 years of suppression
Seed Dormancy	- none to slight - some seed will germinate in fall but most germinate in spring	**Seed Growing Requirements**	- collect cones mid-September to early October when purplish colour - newly germinated seed in greenhouse requires 16 hrs of light daily or they will become dormant - seed requires 20°-30° C to germinate
Seed Stratification	artificial: cold stratification at 2° to 5° C for 21-30 days recommended	**Wildlife Value**	- food source for deer mouse, voles, red squirrels, birds - provides winter cover for deer
Seed Longevity (in soil seed bank)	<1 year	**Occurrence**	uncommon, restricted distribution
Germination Rate	60-70%	**Conservation Concern**	hybridization with black spruce; hybrids out-compete red spruce when harvesting practices create open conditions
Seed Pests	preferred over balsam fir seeds by deer mice, voles	**Silvicultural Concern**	– requires partial cutting system to maintain moisture and shade conditions to out-compete other species and black/red hybrids – shallow-rooted, subject to windthrow
Seedling Pests	crushing by hardwood litter and snow	**Mature Tree Pests**	damaged by spruce budworm
Sprouting Ability	rarely layers	**Other**	- very susceptible to fire - susceptible to windthrow

Rock Elm

Ulmus thomasii Sarg.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	300, typically 250	**Site: Moisture Requirements**	moist, well-drained sites
Fruiting Age (years)	20, peaks at 45-125	**Site: Nutrient Requirements**	- sandy-loam, loam, silt loam - often on shallow soil over bedrock - wide ranges of pH (slightly alkaline to neutral to strongly acidic
Seedcrop Periodicity (years)	3-4	**Climatic Range in Ontario**	- near northern limit of natural range - all of Deciduous Forest Region - southern part of Great Lakes-St. Lawrence Forest Region (best described as Site Districts 6E(9,10,11,12,14,15))
Flower Type/Pollination Mechanism	perfect wind	**Genetics**	hybridizes with slippery elm
Seed Dispersal	May to June	**Seedbed Type**	humus soils (rich)
Dispersal Method	- wind - water - small mammals - birds	**Shade Tolerance**	intermediate, less tolerant with age
Dispersal Distance	- 30-50 m - many kilometers if transported by birds, small mammals or water	**Light Requirements**	seedlings: prefer light, but are shade tolerant until after sapling stage when become more light demanding
Seed Weight	very light	**Shade Requirements**	
Seed Production	no data	**Response to Release**	recovers successfully after long periods of suppression at seedling-sapling stage
Seed Dormancy	none, germinate in same season	**Seed Growing Requirements**	sow immediately
Seed Stratification	none required	**Wildlife Value**	seeds: relished by rodents buds: food for deer, rabbits, squirrels, birds
Seed Longevity (in soil seed bank)	< 1 year	**Occurrence**	uncommon, more so in recent years
Germination Rate	- 70-80 % (artificially) - very low (naturally)	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	small mammals	**Silvicultural Concern**	- functionally depleted from landscape due to Dutch elm disease - very large trees likely to be resistant, should be retained
Seedling Pests	- large, small mammals - birds - frost	**Mature Tree Pests**	susceptible to Dutch elm disease
Sprouting Ability	sprouting, suckering can occur but are uncommon	**Other**	

Sassafras

Sassafras albidum (Nutt.) Nees

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	500, typically 100	**Site: Moisture Requirements**	fresh sites
Fruiting Age (years)	10, peaks at 25-50	**Site: Nutrient Requirements**	- nutrient-rich to poor - found on all soil types within its range - grows best on well-drained sandy loam soils - pH optimum range 6.0-7.0
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- near northern part of natural range - limited to Deciduous Forest Region
Flower Type/Pollination Mechanism	dioecious no data	**Genetics**	no genetic variation has been reported
Seed Dispersal	August to September	**Seedbed Type**	mineral soils
Dispersal Method	- birds - water - small mammals (possibly)	**Shade Tolerance**	intolerant
Dispersal Distance	vicinity of parent tree	**Light Requirements**	germination: requires light provided by canopy openings
Seed Weight	light	**Shade Requirements**	no data
Seed Production	no data	**Response to Release**	no data
Seed Dormancy	biochemical inhibition causes strong dormancy requiring cold stratification	**Seed Growing Requirements**	sow pretreated seeds in February
Seed Stratification	artificial: 150 days at 1^o-4^o C natural: 120 days at 5^o C on moist forest floor	**Wildlife Value**	fruit: good food source for birds bark, leaves, twigs: browsed by deer primary host for spicebush swallowtail butterfly
Seed Longevity (in soil seed bank)	6 years	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	no data	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	birds	**Silvicultural Concern**	first species to die if overtopped in mixed stands
Seedling Pests	- deer - defoliators, root borers - leaf spot - Verticillium wilt - Nectria canker on saplings	**Mature Tree Pests**	- deer eat bark, twigs, leaves - root borers, defoliators, sucking insects - leaf blight
Sprouting Ability	sprouts readily from roots, stumps, often forming colonies	**Other**	- highly susceptible to fire damage (all ages) - saplings susceptible to Armillaria - good self-pruner in well-stocked stands - considered a good choice for restoring depleted soils in old fields - allelopathy used to maintain itself aggressively in a relatively pure and mature forest (allelopaths include 2-pinene, 3- phellandrene, eugenol, safrole, citrol, s-camphor)

Shagbark Hickory

Carya ovata (Miller) K. Koch var. *ovata*

Biological Features		Ecological Features	
Tree Longevity (years)	>300, typically 250	**Site: Moisture Requirements**	- prefers moist sites - grows on dry to moist sites
Fruiting Age (years)	40, peaks at 60-200	**Site: Nutrient Requirements**	- prefers fertile sites - loam, clay soils - shallow soils over limestone - most commonly on somewhat calcareous sites
Seedcrop Periodicity (years)	1-3	**Climatic Range in Ontario**	- near northern part of natural range - throughout Deciduous Forest Region - parts of Great Lakes-St. Lawrence Forest Region (best described as Site Districts 6E(9,10,11,12,15)); isolated stands near Lake Huron (6E(5)), Georgian Bay (6E(6))
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- 2 varieties recognized - hybridizes with other hickories (big shellbark, bitternut); shagbark X pecan has been reported - 5 named clones of shagbark-pecan hybrids; 3 cultivars of shagbark-shellbark hybrids; 7 cultivars of shagbark-bitternut hybrids
Seed Dispersal	September to December	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - squirrels, chipmunks	**Shade Tolerance**	intermediate
Dispersal Distance	- vicinity of parent tree - greater distance if transported by animals	**Light Requirements**	seedlings: grow well under full sunlight or light shade
Seed Weight	heavy	**Shade Requirements**	no data
Seed Production	53-70 l nuts /tree	**Response to Release**	saplings, stump sprouts, root suckers respond rapidly
Seed Dormancy	biochemical inhibition overcome naturally by overwintering in duff or artificial stratification	**Seed Growing Requirements**	sow untreated nuts in fall at depth 2X nut diameter, mulching necessary until germination complete; sow pretreated nuts in spring at depth 2X nut diameter
Seed Stratification	90-120 days at 3^{o}-5^{o} C	**Wildlife Value**	nuts: important food source for squirrels, other wildlife, including black bear, deer, coyote, red fox, rabbits, mice, mallards, wood ducks, wild turkey seedlings, leaves, twigs: seldom browsed by deer
Seed Longevity (in soil seed bank)	1 year	**Occurrence**	common
Germination Rate	50-75% (natural)	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- small, large mammals - birds - insects (hickory shuckworm, pecan weevil, hickory curculios)	**Silvicultural Concern**	- slow growth places it at distinct disadvantage under even-aged management - suitable to management on long rotations (~ 200 years)
Seedling Pests	- insects (twig girdler, twig pruner) - anthracnose - mildew, leaf spots	**Mature Tree Pests**	Armillaria
Sprouting Ability	- sprouts prolifically after cutting or fire - sprouts more common on 20-24 cm stumps; root suckers on larger stumps	**Other**	- susceptible to damage by fire - slow growing

Shumard Oak[1]

Quercus shumardii Buckley

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	moist to wet sites
Fruiting Age (years)	25, peaks after 50	**Site: Nutrient Requirements**	- fertile, well-drained soils, but tolerant of sites associated with nutrient deficiencies - clay, loam, clay-loam soils - preferred pH 7.5
Seedcrop Periodicity (years)	2-3	**Climatic Range in Ontario**	- at northern part of its natural range - limited to Deciduous Forest Region, specifically in along Lake Erie in Site District 7E(1)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- 2 varieties, and 6 hybrids - hybridizes with pin, red, black oaks
Seed Dispersal	September to October	**Seedbed Type**	mineral soils
Dispersal Method	squirrels birds rodents, gravity, water	**Shade Tolerance**	intolerant
Dispersal Distance	vicinity of parent tree	**Light Requirements**	requires full sunlight for good reproduction
Seed Weight	moderate	**Shade Requirements**	no data
Seed Production	- no data - species frequently produces multi-seeded acorns	**Response to Release**	70-76% epicormic branching after seed cut in unmanaged bottomland stands has been reported
Seed Dormancy	biochemical inhibition overcome with cold stratification or natural prechilling	**Seed Growing Requirements**	sow in fall to depth of 2X seed diameter
Seed Stratification	60-120 days at 0^{o}-5^{o} C	**Wildlife Value**	acorns: excellent food source for wildlife, including deer, squirrels, birds
Seed Longevity (in soil seed bank)	< 1 year	**Occurrence**	- rare, usually between 21-100 occurrences in Ontario - vulnerable in Canada
Germination Rate	no data	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- deer, squirrels - acorn weevil	**Silvicultural Concern**	- unless decaying/diseased, mature stems should not be removed - to encourage regeneration on appropriate sites, consider creating an opening in forest canopy at least 1 tree height in diameter in vicinity of mature, seed-producing stems; provide some mechanical disturbance (logging) to expose patches of mineral soil; monitor regeneration and be prepared for follow-up tending
Seedling Pests	- deer, rabbits - defoliators, borers - leaf blister, leaf spot - anthracnose	**Mature Tree Pests**	no data
Sprouting Ability	does not sprout readily on moist sites	**Other**	- at maturity, retards growth of competing understory vegetation by allelopathy - moderately fast growing

[1] *Status Report prepared, August, 1983*

Silver Maple

Acer saccharinum L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 130	**Site: Moisture Requirements**	- moist sites - tolerates temporary flooding
Fruiting Age (years)	11	**Site: Nutrient Requirements**	- very fertile soils - growth stunted on potassium-deficient soils - more common on organic soils than medium to fine-textured mineral soils; rarely occurs on clays, gravels - grows best on calcareous muck soils superimposed on sand over impervious clay or bedrock - pH optimum range 4.5-8.0
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- throughout Deciduous Forest Region - throughout eastern part of Great Lakes-St. Lawrence Forest Region; in west, scattered areas of Site Regions 4W, 5S
Flower Type/Pollination Mechanism	polygamo-dioecious; monoecious or dioecious insects or wind	**Genetics**	- hybridizes with red maple
Seed Dispersal	April to June	**Seedbed Type**	- mineral/humus mix - most silver maple sites are seasonally flooded, it is critical for seeds to land on a suitable seedbed above the water line
Dispersal Method	- wind - water (occasionally)	**Shade Tolerance**	tolerant to intermediate; depends on site quality
Dispersal Distance	-effective range of only 100 m	**Light Requirements**	- dense overstory can depress first year germination - for seedlings to survive they must be released from under closed canopy
Seed Weight	moderate	**Shade Requirements**	germination: requires partial shade
Seed Production	good seed crops are produced every 1-2 years	**Response to Release**	- young trees respond very well - thinned trees experience significant increases in diameter
Seed Dormancy	none	**Seed Growing Requirements**	sow immediately after dispersal; cover with 1.2cm soil; seedlings require 2,000-2,500 hours of chilling to break dormancy
Seed Stratification	none required	**Wildlife Value**	buds: excellent food source for squirrels trunks: excellent denning sites for squirrels, raccoons, other mammals, wood ducks, goldeneye ducks, woodpeckers bark: valuable food source for beaver
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	97%	**Conservation Concern**	no data
Seed Pests	squirrels, other rodents	**Silvicultural Concern**	to encourage regeneration, time canopy openings to coincide with good seed crops, drier springs and the species' spring seed dispersal; tending may be required on rich lowland sites
Seedling Pests	- deer, rabbits - defoliators - leaf spots, tar spot, leaf blister, anthracnose, powdery mildew, Verticillium wilt, Rhizoctonia, charcoal root rot	**Mature Tree Pests**	- Armillaria - saplings susceptible to Nectria canker
Sprouting Ability	- sprouting from stumps or root collars common - root suckering also reported - layering possible under artificial conditions	**Other**	- highly susceptible to ice damage - fast growing

Slippery Elm

Ulmus rubra Muhlenb.

Biological Features		Ecological Features	
Tree Longevity (years)	300, typically 200	Site: Moisture Requirements	- moist sites - can persist on poorly drained soils that are occasionally flooded for periods of 2 or 3 months
Fruiting Age (years)	15, peaks at 25-125	Site: Nutrient Requirements	- fertile soils - sandy-loam soil
Seedcrop Periodicity (years)	2-4	Climatic Range in Ontario	- near northern limit of natural range - throughout Deciduous Forest Region - southern fringe of Great Lakes-St. Lawrence Forest Region, more specifically southern edges of Site Districts 6E(10,11,12,15) into 5E(11)
Flower Type/Pollination Mechanism	perfect wind	Genetics	- no studies of genetic diversity reported - hybridizes with rock elm
Seed Dispersal	April to June	Seedbed Type	mineral soils
Dispersal Method	- wind - water (occasionally)	Shade Tolerance	tolerant
Dispersal Distance	vicinity of parent tree - distance 2X parent tree height	Light Requirements	seedlings: thrive in full sunlight, light shade
Seed Weight	light	Shade Requirements	none
Seed Production	no data	Response to Release	no data
Seed Dormancy	sometimes, lacks deep dormancy	Seed Growing Requirements	sow seeds immediately after ripening
Seed Stratification	none required	Wildlife Value	seeds: food for birds, small mammals seedlings, twigs: browsed by deer, rabbits
Seed Longevity (in soil seed bank)	1 year	Occurrence	common
Germination Rate	no data	Conservation Concern	no data
Seed Pests	- squirrels, mice - birds	Silvicultural Concern	protect very large trees that may be resistant to Dutch elm disease
Seedling Pests	- deer, rabbits - defoliators, borers - black spot	Mature Tree Pests	- trees susceptible to Dutch elm disease fungus; less susceptible than rock or white elm - Armillaria - elm yellows - saplings susceptible to Nectria canker
Sprouting Ability	- sprouts readily from stumps - suckers from rhizomes at seedling stage - layering is possible	Other	susceptible to ice damage

Spicebush

Lindera benzoin (L.) Blume

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	no data	**Site: Moisture Requirements**	low, moist to well-drained, wet sites of rivers banks, open meadows, sand dunes
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	no data
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- at northern limit of its natural range - common in Deciduous Forest Region (all of Site Region 7E) - limited to north shore of Lake Ontario in Hastings, Northumberland, Prince Edward counties shoreline in Great Lakes - St. Lawrence Forest Region; more specifically 6E (8,13); sporadically northward to Georgian Bay
Flower Type/Pollination Mechanism	dioecious or polygamous	**Genetics**	no data
Seed Dispersal	September to October	**Seedbed Type**	no data
Dispersal Method	songbirds; mainly wood thrush, robin	**Shade Tolerance**	very tolerant
Dispersal Distance	great distances	**Light Requirements**	low light, but tolerates up to near full sun
Seed Weight	heavy	**Shade Requirements**	performs best in shade or semi-shade
Seed Production	1seed/drupe	**Response to Release**	probably increases foliage volume
Seed Dormancy	biochemical inhibition; germinates in spring following cold, moist stratification	**Seed Growing Requirements**	unstratified seed: sow seeds in fall at depth of 2-4X seed diameter, in moist, rich growing medium stratified seed: sow in spring
Seed Stratification	artificial: warm stratification for 1 month followed by 3 months prechilling; beware of mould	**Wildlife Value**	high twigs, fruit: eaten by deer, cottontail rabbit, opossum, pheasant, bobwhite quail, ruffed grouse, numerous songbirds nectar: food source for very early insects - primary host for spicebush swallowtail butterfly - food for Promethea moth larvae - provides good nesting sites for several songbirds
Seed Longevity (in soil seed bank)	until spring	**Occurrence**	common in Site Region 7E; less common in 6E
Germination Rate	70-80%	**Conservation Concern**	no data
Seed Pests	- birds - prone to injury, moulds	**Silvicultural Concern**	
Seedling Pests	no data	**Mature Tree Pests**	- deer browse small trees - Asiatic oak beetle feeds on foliage - anthracnose - Botryosphaeria cankers - Hendersonia leaf spot, twig cankers
Sprouting Ability	excellent; resprouts well after damage	**Other**	- susceptible to winter-kill - aromatic twigs, leaves used for tea - dried berries are powdered as a spice - high demand in ornamental gardens

Striped Maple

Acer pensylvanicum L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	~100	**Site: Moisture Requirements**	moist to fresh sites
Fruiting Age (years)	no data	**Site: Nutrient Requirements**	- common on well-drained, sandy loams - prefers acid soils (optimum range unknown)
Seedcrop Periodicity (years)	no data	**Climatic Range in Ontario**	throughout eastern part of Great Lakes-St. Lawrence Forest Region (absent west of Lake Superior, south of 44°N)
Flower Type/Pollination Mechanism	primarily dioecious, but monoecious also possible; likely influenced by environmental factors no data	**Genetics**	- species is distinct from other native maples - no organized genetics research done
Seed Dispersal	October to November	**Seedbed Type**	decaying wood
Dispersal Method	wind	**Shade Tolerance**	very tolerant
Dispersal Distance	the density of seed dispersal from a tree drops quickly as the distance from the tree increases.	**Light Requirements**	- seedlings more abundant in gap edges - develops best under moderate light provided in partial or small forest openings; does poorly in full sunlight
Seed Weight	light	**Shade Requirements**	germination, seedlings: shade recommended during period of seedling emergence, establishment
Seed Production	varies from tree to tree	**Response to Release**	small trees show instant response to increased light
Seed Dormancy	biochemical inhibition overcome with moist stratification	**Seed Growing Requirements**	sow untreated seeds in fall; pretreated seeds in spring; cover with 0.5-1 cm of soil natural: mature seeds covered current year's leaf litter do not germinate until second year; if buried under soil or humus, germination occurs during first year
Seed Stratification	90-120 days at 5° C	**Wildlife Value**	buds: winter food for birds leaves, young shots: favoured food of moose, deer; preferred by rabbits bark: food for beaver; porcupine
Seed Longevity (in soil seed bank)	no data	**Occurrence**	common
Germination Rate	no data	**Conservation Concern**	no data
Seed Pests	small mammals, deer, moose, caribou, beaver	**Silvicultural Concern**	when large numbers of seedlings occupy understory they frequently become dominant vegetation after cutting, and can exclude more desirable species
Seedling Pests	- moose, deer - Verticillium wilt - leaf spot	**Mature Tree Pests**	- Verticillium wilt - leaf spot
Sprouting Ability	- sprouting, layering possible, but not important to reproduction of species - clonal growth important for enlarging the range of the species	**Other**	- seldom reaches tree height (> 6 m) in Ontario - slow growing

Sugar Maple

Acer saccharum Marshall spp. *saccharum*

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	400, typically 300	**Site: Moisture Requirements**	- moist to fresh sites - does not grow well on dry shallow soils, rarely found in swamps
Fruiting Age (years)	22-30, peaks at 70-100	**Site: Nutrient Requirements**	- well-drained, nutrient rich soils - best on well-drained loams, also on sands, loamy sands, sandy loams, loams, silt loams - pH optimum range 5.5-7.3
Seedcrop Periodicity (years)	3-7	**Climatic Range in Ontario**	throughout Deciduous, Great lakes-St. Lawrence Forest Region
Flower Type/Pollination Mechanism	monoecious insects (bees) or wind	**Genetics**	hybridizes with black, red maples
Seed Dispersal	June to September	**Seedbed Type**	- mineral soils - decaying wood - does not like coniferous litter
Dispersal Method	wind	**Shade Tolerance**	very tolerant
Dispersal Distance	> 100 m	**Light Requirements**	- maximum height growth occurs under 65% full sunlight - maximum photosynthetic activity occurs under 25% full sunlight
Seed Weight	light	**Shade Requirements**	seedlings: at least 55% shade required to retain moisture for best growth until seedlings are 0.6-1.2 m high
Seed Production	22 million samaras/ ha	**Response to Release**	- shows strong response to release before 31 years of age - if released excessively, develops epicormic sprouts
Seed Dormancy	biochemical inhibition overcome with moist stratification	**Seed Growing Requirements**	sow immediately after dispersal in fall at depth of 2X seed diameter
Seed Stratification	35-90 days at 0+^{o} C	**Wildlife Value**	seeds, buds, leaves, twigs: food for squirrels leaves, twigs: browsed by deer; initial deformities are overgrown, corrected without deformity leaves: highly targeted by gypsy moths seedlings: tend to be avoided by deer
Seed Longevity (in soil seed bank)	~ 1 year	**Occurrence**	common
Germination Rate	95%	**Conservation Concern**	no data
Seed Pests	- rodents - birds	**Silvicultural Concern**	- release is necessary to secure dominance, improve growth - monitor for live Asian longhorn beetle infestation - general movement to sugar maple moncultures in Quebec may be contributing to forest decline in that province
Seedling Pests	- squirrels, mice - defoliators, bud miners - Armillaria, anthracnose, leaf spot, Verticillium wilt	**Mature Tree Pests**	- deer browsing - porcupines capable of girdling upper stems - stem cankers, heart rot - small trees susceptible to target and cobra cankers, punk rot
Sprouting Ability	- sprouts, suckers vigorously if tree cut or damage - stump sprouts decrease in number with increased tree size - layering rarely occurs	**Other**	- roots release an exudate that can inhibit growth of yellow birch when root growth periods coincide; other tree species also may be affected - alleopathy effects of aster, goldenrod reduce germination, early seedling growth - sugar maple litter is very acidic; decomposing leaves increase mineral content in soil - early growth is slow

Swamp White Oak

Quercus bicolor Willd.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	typically 300	**Site: Moisture Requirements**	wet sites
Fruiting Age (years)	20, peaks at 75-200	**Site: Nutrient Requirements**	- very fertile soils - imperfectly to poorly-drained mineral soil to muck - sandy-loam, clay - pH optimum range 6.0-7.5
Seedcrop Periodicity (years)	3-5	**Climatic Range in Ontario**	- at northern limit of natural range - southern part of Deciduous Forest Region (Site Districts 7E(1,2,3,4,5)) - very rare in the southernmost parts of Site Region 6E in Great Lakes-St. Lawrence Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	6 hybrids exist
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- gravity - rodents - water	**Shade Tolerance**	intermediate
Dispersal Distance	vicinity of parent tree	**Light Requirements**	no data
Seed Weight	moderately heavy	**Shade Requirements**	seedlings: become established under moderate shade
Seed Production	no data	**Response to Release**	develops epicormic branches
Seed Dormancy	none	**Seed Growing Requirements**	sow acorns in the late fall just below the surface in prepared seedbeds; protect from rodents
Seed Stratification	none required	**Wildlife Value**	acorns: valuable food for deer, squirrels, chipmunks, mice, ducks, ruffed grouse, blue jay
Seed Longevity (in soil seed bank)	1 year	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	78-98%	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - eastern Ontario (Site Region 6E) populations should be protected
Seed Pests	- large, small mammals - ducks, ruffed grouse, blue jays	**Silvicultural Concern**	frequently not recognized during logging operations
Seedling Pests	- rabbits, mice - leaf spot, leaf blister	**Mature Tree Pests**	- oak wilt - saplings susceptible to Nectria canker
Sprouting Ability	- sprouting decreases with increasing stump diameter - resprouting of advanced regeneration following death of the top growth is common	**Other**	

[2] Status Report prepared, October, 1992

Sycamore

Platanus occidentalis L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	500, typically 250	**Site: Moisture Requirements**	- moist to wet sites - will die if the tree is inundated for more than 2 weeks during growing season
Fruiting Age (years)	6-7 for open grown trees 25 in dense natural stands, peaks at 50-200	**Site: Nutrient Requirements**	- fertile soils - grows best on sandy loams or loam - pH optimum range 6.5-7.5
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- near northern part of its natural range - most of Deciduous Forest Region - locally in Site District 6E(6)(near Georgian Bay) of Great Lakes St. Lawrence Forest Region; planted widely in more northerly locations (e.g., to Ottawa)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- 2 varieties named (*Platanus occidentalis* var *glabrata*, *P. occidentalis* var *attenuata*) - geographic variation in growth patterns in sycamore is extensive - displays strong north-south gradient in resistance to a killing stem canker disease
Seed Dispersal	February-April	**Seedbed Type**	mineral soils
Dispersal Method	- wind - water - birds	**Shade Tolerance**	intermediate
Dispersal Distance	transported great distances by water	**Light Requirements**	germination: high light intensities increase germination potential seedlings: require direct light to survive
Seed Weight	light	**Shade Requirements**	no data
Seed Production	no data	**Response to Release**	epicormic branching occurs only with excessive release
Seed Dormancy	none	**Seed Growing Requirements**	sow in spring, cover seeds with 0.6 cm of soil or mulch
Seed Stratification	none required	**Wildlife Value**	seeds: food for some birds
Seed Longevity (in soil seed bank)	no data	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	large percentage usually germinate	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- birds - late frosts very detrimental to seed production	**Silvicultural Concern**	-displays strong north-south gradient in resistance to *Ceratocystis fimbriata f. sp. platani* a killing stem canker disease occurring mainly in southern U.S. forests; controlled through sanitary pruning practices
Seedling Pests	anthracnose	**Mature Tree Pests**	no data
Sprouting Ability	sprouts readily from young stumps (sapling to pole-size)	**Other**	- bark not fire resistant - demonstrated heritable variation in growth, other traits are used for tree improvement programs - fast growing; grows to a larger diameter than any other North American hardwood (reported trees > 302 cm DBH, 43 m in height)

Tamarack

Larix laricina (Du Roi) K. Koch

Biological Features		**Ecological Features**	
Tree Longevity (years)	335, typically 150-180	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	4, usually 12-15, peaks at 75	**Site: Nutrient Requirements**	- rich, well-drained organic and loamy soils - pH optimum range 5.5-7.6
Seedcrop Periodicity (years)	3-6	**Climatic Range in Ontario**	- all forest regions throughout Ontario - small local stands in Site Region 5E - local relict populations in Site Region 7E
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	photoperiodic variation from north to south
Seed Dispersal	September to October	**Seedbed Type**	- mineral soil - organic - sphagnum moss - burned organic soils
Dispersal Method	wind	**Shade Tolerance**	very intolerant
Dispersal Distance	- majority 18 m or a distance 2X height of tree - few 60-70 m	**Light Requirements**	germination: 100% sunlight seedlings: require abundant light
Seed Weight	light	**Shade Requirements**	no data
Seed Production	- 20,000 cones/tree - 300,000 seeds/tree	**Response to Release**	none
Seed Dormancy	none to slight (biochemical inhibition)	**Seed Growing Requirements**	sow seed in fall; cover with 0.6 cm of soil
Seed Stratification	21-60 days (first winter)	**Wildlife Value**	- seeds food source for red squirrel, crossbills - seedlings food source for snowshoe hares - inner bark is food source for porcupine - trees offer nesting areas for osprey, great grey owl
Seed Longevity (in soil seed bank)	≤ 4 years	**Occurrence**	common
Germination Rate	40-50% (could be low as 5%)	**Conservation Concern**	no data
Seed Pests	- rodents - birds - insects	**Silvicultural Concern**	no data
Seedling Pests	- snowshoe hares - larch casebearer - inadequate light - needle rust, needle cast	**Mature Tree Pests**	may be browsed by deer, moose
Sprouting Ability	layering, common at tree line, uncommon but possible elsewhere	**Other**	highly susceptible to fire damage

Trembling Aspen

Populus tremuloides Michx.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	>200, typically 70	**Site: Moisture Requirements**	moist sites
Fruiting Age (years)	10-20, peaks at 50-70	**Site: Nutrient Requirements**	- wide variety of soils ranging from shallow, rocky to deep loamy sands, heavy clays - good soils are loamy, and high in organic matter, calcium, magnesium, potassium, nitrogen - growth in sands often poor because of low levels of moisture, nutrients - pH optimum range 5.3-6.5
Seedcrop Periodicity (years)	4-5	**Climatic Range in Ontario**	all forest regions throughout Ontario
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	8 natural hybrids are recognized
Seed Dispersal	May to June	**Seedbed Type**	- mineral soils - humus
Dispersal Method	- wind - water	**Shade Tolerance**	very intolerant
Dispersal Distance	> 1000 m	**Light Requirements**	root suckers: adequate light essential for secondary growth
Seed Weight	very light	**Shade Requirements**	pole-sized trees: suffer sunscald if suddenly exposed to full sunlight
Seed Production	1.5 million seeds/tree	**Response to Release**	growth increases
Seed Dormancy	none	**Seed Growing Requirements**	do not cover seeds or press into soil; keep moist for first month after germination
Seed Stratification	none required	**Wildlife Value**	stands: provide habitat for wide variety of forest wildlife, particularly for ruffed grouse buds: food for ruffed, sharp-tailed grouse leaves: food for ruffed grouse buds, leaves, twigs: food for deer, moose, caribou, hares, rabbits mice (low tolerance to browsing damage) bark: food for beaver, hares, rabbits, mice, voles
Seed Longevity (in soil seed bank)	2-4 weeks	**Occurrence**	common
Germination Rate	> 75%	**Conservation Concern**	no data
Seed Pests	mice, voles	**Silvicultural Concern**	no data
Seedling Pests	- deer, hares, rabbits - insects - ceratocystis leaf spot and canker - Venturia leaf, shoot blight - ink spot - hypoxylon	**Mature Tree Pests**	- saplings susceptible to Nectria canker - coppice stands susceptible to Armillaria root disease
Sprouting Ability	- suckering is common (light to moderate burning on heavy cut areas stimulates suckering, growth) - sprouting occurs on young stumps; most after late September cut; fewest after late August - frequently regenerates by vegetative means after fire	**Other**	- highly susceptible to fire - play important role in nutrient cycling - good self-pruner - fast growing - roots form ectomycorrhizae if suitable inoculum is present

Tulip Tree[2]

Liriodendron tulipifera L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 400, typically 200	**Site: Moisture Requirements**	- fresh to dry sites - rarely does well on very wet or very dry sites
Fruiting Age (years)	30-40, peaks at 40-100	**Site: Nutrient Requirements**	- deep, fertile soils - sand, sandy-loam soils - low levels of soil nutrients (N,P,K) can limit growth
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- near northern limit of natural range - limited to Deciduous Forest Region in extreme southwestern Ontario near Great Lakes (Site Districts 7E(1,2,3,5))
Flower Type/Pollination Mechanism	perfect insects (flies, beetles, honey bees)	**Genetics**	- 1 distinct ecotype of tulip tree has been confirmed (North Carolina, U.S.) - variation for wood, tree properties has been demonstrated
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	wind	**Shade Tolerance**	intolerant
Dispersal Distance	- 4-5X tree height - 180 m possible	**Light Requirements**	seedlings: 3% < 10% full sunlight, 1-2 months after germination improves growth
Seed Weight	moderate	**Shade Requirements**	side shade promotes height growth, reduces side branching
Seed Production	200,000-400,000 seeds/tree	**Response to Release**	- epicormic branching high (70-76%) after seed cut in unmanaged bottomland stand - seedling-sapling stage, dominant and codominant crown classes are little affected by thinning, cleaning - intermediate and overtopped trees of good vigour respond in diameter, height growth
Seed Dormancy	biochemical inhibition is overcome over winter under natural conditions; or by cold stratification under controlled conditions	**Seed Growing Requirements**	collect, sow seeds as soon as colour changes to yellowish-brown; sow in fall to depth 2X seed diameter; may not germinate until second spring; pretreated seeds should be sown in spring natural: seedbed disturbance (scarification, fire) can increase germination significantly
Seed Stratification	70-90 days at 0^{o}-$10\,^{o}$C in moist sand	**Wildlife Value**	seeds: food for squirrels, rabbits, mice, quail, purple finch) bark, twigs: deer, rabbits
Seed Longevity (in soil seed bank)	3-7 years	**Occurrence**	uncommon to locally common, demonstrably secure in Ontario
Germination Rate	germination very low (2%) under shaded conditions	**Conservation Concern**	- southern Ontario range represents ≥ 80% of species' range in Canada - long-term survival depends on public education, recognition of species uniqueness
Seed Pests	- small mammals - birds	**Silvicultural Concern**	on appropriate sites (e.g., in areas with low deer density) to encourage regeneration, create openings that are at least 1 tree height and up to 2X tree height in diameter; disturb soil (e.g., by logging) to expose mineral soil; monitor regeneration
Seedling Pests	- deer - scale insects - fire	**Mature Tree Pests**	- deer (eliminated in areas with heavy browsing) - heartwood rot, root rot, canker
Sprouting Ability	sprouting decreases with increased stump diameter	**Other**	- extremely susceptible to fire damage - larger openings in the canopy allow greater phenolic production, fewer pest problems - fast growing

[2] *Status Report prepared, October, 1992*

White Ash

Fraxinus americana L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	300, typically 260	**Site: Moisture Requirements**	dry to moist sites
Fruiting Age (years)	20, peaks sometime before 175	**Site: Nutrient Requirements**	- demanding soil fertility requirements - most commonly on fertile soils with a high nitrogen content, moderate to high calcium content - moderately well-drained sand, clay-loam, sandy-loam soils - pH optimum range 5.0-7.5
Seedcrop Periodicity (years)	3	**Climatic Range in Ontario**	throughout Deciduous, Great Lakes-St. Lawrence Forest Regions
Flower Type/Pollination Mechanism	dioecious wind	**Genetics**	hybridization with other ash species extremely rare
Seed Dispersal	September to December	**Seedbed Type**	- humus/mineral mix - seedlings do not like littoral sand as seedbed
Dispersal Method	wind	**Shade Tolerance**	intermediate; more tolerant when young
Dispersal Distance	140 m	**Light Requirements**	germination: best in 45% full sunlight seedlings: can survive < 3% full sunlight
Seed Weight	light	**Shade Requirements**	- development of good timber trees requires shading to reduce branchiness, provide competition - early shade tolerance helps invasion in old-field situations
Seed Production	no data	**Response to Release**	- little to no epicormic branching after seed cut in unmanaged bottomland - responds readily to thinning, but little to no response to release after 31 years
Seed Dormancy	biochemical inhibition, physical properties of seedcoat best overcome under artificial situation with combination warm/cold stratification	**Seed Growing Requirements**	collect, sow seeds as soon as colour changes to yellowish-brown; sow to depth of 2X seed diameter
Seed Stratification	30 days at 20^{o}-30^{o}C then 60 days at 5^{o} C	**Wildlife Value**	seeds: food source for wood ducks, northern bobwhite quail, purple finch, pine grosbeak, squirrels seedlings: preferred browse in old-field situations bark: young trees provide food for rabbits, beaver, porcupine, mice, voles
Seed Longevity (in soil seed bank)	3-5 years	**Occurrence**	common
Germination Rate	54%	**Conservation Concern**	no data
Seed Pests	- squirrels, mice - birds	**Silvicultural Concern**	no data
Seedling Pests	- deer, rabbits - defoliators, borers - leaf spot - anthracnose	**Mature Tree Pests**	no data
Sprouting Ability	stumps sprout readily	**Other**	- bark is not fire resistant - easily damaged by browsing, but 1 of less preferred deer browse species - susceptible to girdling by voles when boles ≤ 20-30 cm DBH - sensitive to air pollution - ash decline is very serious problem; may be caused by ash yellows or environmental stress

White Birch

Betula papyrifera Marshall

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	140-200, typically 100	**Site: Moisture Requirements**	moderately dry to very moist sites
Fruiting Age (years)	15, peaks at 40-70	**Site: Nutrient Requirements**	- wide variety of soils - nutrient sensitive, greater growth possible with fertilizer inputs - grows best on sandy loams - pH optimum range 5.0-7.0
Seedcrop Periodicity (years)	1-2	**Climatic Range in Ontario**	- all forest regions - limited to north of Lake Ontario in Deciduous Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- 6 recognized varieties - hybridizes naturally with most every other native birch species
Seed Dispersal	September-November	**Seedbed Type**	- mineral soils - humus - decaying wood
Dispersal Method	- wind - secondary seed dispersal over snow possible	**Shade Tolerance**	very intolerant
Dispersal Distance	> 100 m	**Light Requirements**	germination: exposure of seed to 8+ hours of light/day overcomes prechilling requirements seedlings: grow best in 50% full sunlight; show flexibility of response to changing light levels but eventually suffer in shaded microsites; are more abundant in large gaps, gap centres; increase in number with increasing gap size
Seed Weight	light	**Shade Requirements**	germination: partial shade
Seed Production	- >86 million seeds/ha - extremely heavy seed crops can result in crown deterioration, reduced growth	**Response to Release**	- good growth after heavy release after 31 years - response decreases with maturity (60 years of age) - suppressed trees die unless released early
Seed Dormancy	biochemical inhibition allows some seeds to lie dormant on forest floor for > 1 year, especially following heavy seed crops, dry years	**Seed Growing Requirements**	sow seed in fine peat-sand mixture in late fall, mulch lightly with straw, keep moist, in partial shade during-after germination; for best results plant dormant seeds in spring
Seed Stratification	75 days at 0^o-5^o C or exposure to light overcomes dormancy	**Wildlife Value**	stands: good wildlife cover seedlings: often over- browsed by deer, moose, hares seeds: food for redpoll, pine siskin, chickadees leaves: food for hares catkins, buds: food for ruffed grouse inner bark, branches: food for porcupine
Seed Longevity (in soil seed bank)	> 1 year	**Occurrence**	common
Germination Rate	34%	**Conservation Concern**	no data

White Birch *continued*

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Seed Pests	birds	**Silvicultural Concern**	stands exhibiting post-logging decadence can be avoided by: periodic thinnings to maintain stand vitality; avoiding heavy partial cuttings in previously untreated mature stands
Seedling Pests	- deer, moose, hares - defoliators - Armillaria, leaf spot, anthracnose	**Mature Tree Pests**	- susceptible to logging damage leading to decay or mortality - saplings susceptible to Nectria canker
Sprouting Ability	young stumps sprout prolifically	**Other**	- susceptible to fire damage

White Elm

Ulmus americana L.

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Tree Longevity (years)	> 300, typically 175	**Site: Moisture Requirements**	- wet sites - peaks of establishment after drier-than-average springs
Fruiting Age (years)	15, peaks at 40-150	**Site: Nutrient Requirements**	- very fertile soils; best growth on rich loams - well-drained sands, organic bogs, undifferentiated silts, poorly drained clays, many intermediate combinations - pH optimum range 5.5-8.0
Seedcrop Periodicity (years)	annually	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Region - Boreal Forest Region excluding Site Regions 1E, 2W, northern half of 2E
Flower Type/Pollination Mechanism	perfect wind	**Genetics**	- hybridization with other elms is rare - remaining large, resistant (to Dutch Elm Disease) individuals are too isolated to breed successfully
Seed Dispersal	May to June	**Seedbed Type**	- mineral soil - decaying wood - humus
Dispersal Method	- wind - water	**Shade Tolerance**	tolerant to intermediate
Dispersal Distance	- most seed falls within 90 m, some carried 400 m - greater distances if transported by water	**Light Requirements**	germination: increases in light, but can germinate in dark seedlings: best growth with 33% full sunlight during first year; after 1-2 years, do best in full sunlight
Seed Weight	moderately light	**Shade Requirements**	no data
Seed Production	prolific	**Response to Release**	growth rate increases
Seed Dormancy	none	**Seed Growing Requirements**	sow seed immediately after dispersal just below soil surface, keep moist, partially shaded
Seed Stratification	none required	**Wildlife Value**	seeds: food for squirrels, opossum, mice, ruffed grouse, northern bobwhite quail, hungarian partridge flower buds, flowers, fruit: food for squirrels
Seed Longevity (in soil seed bank)	~1 year	**Occurrence**	non-resistant elms that are too young for beetle to enter but old enough to flower are very common
Germination Rate	no data	**Conservation Concern**	- Dutch elm disease contributes to decline, death of most elms reaching ≥15-25 cm DBH - large (>25 cm DBH), mature stems free of disease are increasingly rare; wherever possible maintain these in forest stands, hedgerows, etc.; report such individuals to: *Elm Recovery Project* *The Arboretum, University of Guelph* *Guelph, ON N1G 2W1* *arboretu@uoguelph.ca*

White Elm *continued*

BIOLOGICAL FEATURES		ECOLOGICAL FEATURES	
Seed Pests	- small mammals - birds	**Silvicultural Concern**	Dutch elm disease precludes silvicultural treatments that encourage species regeneration
Seedling Pests	- defoliators, bark beetles, borers, twig girdlers - phloem necrosis, Verticillium wilt (viruses); black spot, elm yellows (possibly) - frost, fire	**Mature Tree Pests**	- defoliators, bark beetles, borers, twig girdlers - Dutch elm disease
Sprouting Ability	- stumps sprout readily, particularly small stumps - root suckers possible	**Other**	- good shade, hedgerow species since leaves not eaten by cattle - fast growing

White Oak

Quercus alba L.

Biological Features		Ecological Features	
Tree Longevity (years)	600, typically 300	**Site: Moisture Requirements**	- wide range of sites - prefers moist sites
Fruiting Age (years)	20, peaks at 50-200	**Site: Nutrient Requirements**	- very fertile, deep soils - found on sandy plains, gravelly ridges, rock barrens, rich uplands, well-drained loamy soils - mineral nutrition is not limiting to growth except on very sandy soils where moisture is also a limiting factor
Seedcrop Periodicity (years)	4-10	**Climatic Range in Ontario**	- at northern limit of natural range - throughout Deciduous Forest Region - parts of Great Lakes-St. Lawrence Forest Region (including Site District 5E(12), most of Site Region 6E)
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	hybridizes with swamp white, bur, chinquapin oaks
Seed Dispersal	September to October	**Seedbed Type**	humus/mineral mix
Dispersal Method	- squirrels, mice - blue jays - gravity	**Shade Tolerance**	intermediate (most tolerant when young)
Dispersal Distance	- vicinity of parent tree - 60 m when transported by squirrels or birds	**Light Requirements**	germination: aided by light conditions seedlings: for best growth, require at least 35% full sunlight
Seed Weight	moderately heavy	**Shade Requirements**	no data
Seed Production	~1,000 acorns/tree	**Response to Release**	- sapling-, pole-sized trees respond well to release - increases in diameter growth are common, only intermediate and suppressed crown classes exhibit increases in height growth - epicormic branching can be heavy
Seed Dormancy	none	**Seed Growing Requirements**	sow at a depth 2X acorn diameter, immediately after dispersal in fall
Seed Stratification	none required	**Wildlife Value**	acorns: food for mammals, including deer; more than 180 different birds twigs, leaves: browse for deer
Seed Longevity (in soil seed bank)	< 1 year	**Occurrence**	common
Germination Rate	50-99%	**Conservation Concern**	southern Ontario range represents ≥ 80% of species' range in Canada
Seed Pests	- mammals - birds - acorn weevils	**Silvicultural Concern**	no data
Seedling Pests	- deer - defoliators, twig pruners, borers - Armillaria - leaf spot, leaf blister	**Mature Tree Pests**	- favorite of gypsy moth - oak wilt - saplings susceptible to Nectria canker
Sprouting Ability	- young stumps sprout vigorously after being cut or burned - ability to sprout increases with increasing diameter of stumps to 15 cm; decreases with increasing stump diameter over 15 cm - resprouting of advanced regeneration following death of top growth is common	**Other**	- slow growing

White Spruce

Picea glauca (Moench) Voss

Biological Features		Ecological Features	
Tree Longevity (years)	1,000, typically 250-350	**Site: Moisture Requirements**	- moist to fresh sites - will occur on wet to dry sites
Fruiting Age (years)	4, peaks at >30	**Site: Nutrient Requirements**	- wide range of soils - best on sandy, coarse loamy soils - also found on heavy clays-alluvial plains - pH optimum range 4.7-6.5
Seedcrop Periodicity (years)	2-6	**Climatic Range in Ontario**	- at southern limit of natural range - found in all forest regions in Ontario
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	large genetic variation within population, individual trees
Seed Dispersal	- September to January - majority fall before winter with favourable climatic conditions	**Seedbed Type**	- mineral soil - humus/soil mix - decaying wood - burned duff - pioneer mosses
Dispersal Method	- wind - red squirrel cone caches	**Shade Tolerance**	intermediate to tolerant
Dispersal Distance	50-100 m	**Light Requirements**	germination: light required seedlings: require >15% sunlight (growth greatest at full sunlight)
Seed Weight	light	**Shade Requirements**	no data
Seed Production	12,000 cones/tree (=35 l/tree = 250,000 seeds/ tree)	**Response to Release**	- good (from early age to 200 years) - ability related to type of release, degree of damage sustained during release
Seed Dormancy	biochemical inhibition: requires stratification	**Seed Growing Requirements**	cover seed with soil to depth of 2 X seed diameter
Seed Stratification	artificial: 21-30 days at 2-5^{o} C	**Wildlife Value**	- cover, food: for red squirrels, spruce grouse - not a preferred browse species - cover for marten, wolves, foxes, coyotes
Seed Longevity (in soil seed bank)	- <2 years on forest floor - 1-2 years in a cone cache	**Occurrence**	common
Germination Rate	- 55-70% - warm soils cause higher germination - cold growing seasons cause low seed viability - seed viability best in high production years	**Conservation Concern**	- southern Ontario populations represent southern limit of natural range, are small, fragmented - should try to maintain, regenerate white spruce if possible
Seed Pests	- red squirrels, mice, meadow voles, chipmunks, shrews - chickadees, grosbeaks, juncos, sparrows - spruce cone maggot, spruce seed moth	**Silvicultural Concern**	no data
Seedling Pests	- hares - nematodes - snow blight - Armillaria root disease - needle rust - desiccation	**Mature Tree Pests**	Tomentosus
Sprouting Ability	none	**Other**	highly susceptible to fire damage

Yellow Birch

Betula alleghaniensis Britton

Biological Features		**Ecological Features**	
Tree Longevity (years)	> 300, typically 150	**Site: Moisture Requirements**	moist to wet sites
Fruiting Age (years)	30-40, peaks at 70	**Site: Nutrient Requirements**	- grows best in fertile loams, sandy loams - limited growth in acid sandy soils can be overcome with deep fertilizing with phosphorus and lime - pH optimum range 4.0 to 7.5
Seedcrop Periodicity (years)	1-4	**Climatic Range in Ontario**	- throughout Deciduous, Great Lakes-St. Lawrence Forest Regions - southern edge of Boreal Forest Region
Flower Type/Pollination Mechanism	monoecious wind	**Genetics**	- shows great phenotypic variation in various characteristics - 2 varieties, hybridize readily with other native species of birch
Seed Dispersal	August to spring	**Seedbed Type**	- mineral soils - burned duff - humus - decaying wood
Dispersal Method	wind	**Shade Tolerance**	intermediate
Dispersal Distance	100-1,000 m over crusted snow	**Light Requirements**	germination: exposure of seed to 8+ hours of light/day overcomes prechilling requirements seedlings: optimum of 45-50% full sunlight for first 5 years promotes top growth, root development
Seed Weight	light	**Shade Requirements**	germination: partial shade seedlings: moderate side-shade beneficial during first 5 years
Seed Production	< 89 million seeds/ha	**Response to Release**	≥5-year-old seedlings demonstrate best survival, growth, quality improvement after release
Seed Dormancy	biochemical inhibition occurs in ~3% of seed bank, overcome by prechilling	**Seed Growing Requirements**	sow seeds in fall in fine peat-sand mixture, keep moist, partially shaded; protect seedlings from deer natural: controlled burning in vicinity of seed trees promotes germination
Seed Stratification	4-8 weeks at 5^{o} C or exposure to light overcomes dormancy	**Wildlife Value**	seeds: food for squirrels, mice, ruffed grouse, redpolls, other song birds seedlings, leaves, twigs: browse for deer, red squirrels catkins, buds: ruffed grouse mature trees: porcupine, sapsuckers
Seed Longevity (in soil seed bank)	2 years	**Occurrence**	common
Germination Rate	20% (natural conditions)	**Conservation Concern**	no data
Seed Pests	- deer, squirrels - redpolls, ruffed grouse	**Silvicultural Concern**	heavy seed crops can result in crown deterioration and reduced growth
Seedling Pests	- deer, hares, red squirrels - defoliators - Diaporthe canker - shoot blight, leaf spot - fire, late spring frosts - susceptible to aluminum and manganese toxicity	**Mature Tree Pests**	- deer (low tolerance to browsing) - Nectria stem disease - saplings susceptible to Nectria canker - Diaporthe canker
Sprouting Ability	sprouting of mature stems rare	**Other**	- susceptible to fire damage an alleopathic relationship between yellow birch, sugar maple seedlings has been noted - slow growing

Appendix C

Performing a Forest Stand Inventory

This Appendix has been abridged from:

Making Cents out of Forest Inventories: A guide for small woodlot owners. Science Development and Transfer Series No. 002. Copies of this publication are available at a cost of $9.99 (at the timeof this printing) from the OMNR Natural Resources Information Center in Peterborough, Ontario. Telephone: 1-800-667-1940; French: 1-800-667-1840. Fax: (705) 755-1677, email: mnr.nric@mnr.gov.on.ca. webpage: www.mnr.gov.on.ca

This document provides more specific information than this appendix. It includes discussions about the prerequisite skills for conducting forest inventories (e.g., how to map significant features, measure and mark trees, design and locate a sample plot, and compile the forest inventory data).

The main steps to performing a stand inventory are briefly described below. Readers are urged to work through the tables and the calculations.

Step 1: Obtain all important background information about the site

This information will be used to establish property boundaries, prepare management and forest compartment maps, and plan forest operations.

Useful maps include:

- topographical maps
- Forest Resource Inventory (FRI) maps, available from the OMNR
- Ontario Base Maps, available from the OMNR
- County Soils maps are available from Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFR)

Other useful information includes:

- aerial photographs (black and white or color infrared) of the site and surrounding landscape, available from the Natural Resources Information Center (1-800-667-1940)
- past land use information (previous and local landowners are often sources of this information)
- local climatic information (e.g., frost-free days, rainfall), available from Environment Canada and OMAFRA offices
- Canada Land Inventory information and maps, available from Environment Canada in Ottawa
- wildlife habitat information, available from local OMNR and Conservation Authority offices
- location of rare species, available from OMNR district ecologists
- forest management and silvicultural background information contained in various *Extension Notes* that are available from the Landowner Resource Center in Manotick, Ontario (1-800-387-5304)

Step 2: Begin to prepare maps of site

The site boundaries are mapped. Use one transparent overlay for each site resource (e.g., forest cover, soils, roads, topography, water, important wildlife habitat) to map major zones and combine these to develop an overall map of the site. This process helps to identify the resource potential of site, identify potential conflicts, and visualize some effects of proposed forestry activities.

Step 3: Decide on more specific information to collect

Information that is most commonly collected includes:

- tree species composition and distribution across the site
- overall health and quality of trees
- tree age, diameter, size (DBH)
- stand height, density, volume
- site characteristics and their location (e.g., soil type, drainage, topography, access, microclimates, potentially sensitive areas)
- environmental sensitivity of the site and parts of the site to potential logging damage
- significant wildlife habitats (e.g., raptor nests, patches of conifer cover, woodland ponds, seepage areas)
- presence of rare species or species of conservation concern (e.g., plants such as ginseng, declining species, nesting birds of conservation concern)
- history of the forest (e.g., past management, natural disturbances such as fire, storms)

Step 4: Design the forest inventory cruise

The most important components of a typical forest inventory cruise are:

- the number and location of sample plots
- the provision of accurate information that reflects the character of the forest stand on the site

In general, more plots are required for variable terrain and when more accurate information is required. Also a larger budget for an inventory is usually allotted for sites with high timber value. Sampling intensity varies from 0.5 to1 % of the total woodlot area for a reconnaissance survey of large forested areas, to approximately 2 to 10 % of the total area of smaller woodlots.

The number of sample units required depends on the sampling intensity and size of the sample unit. The most popular plot size used in forest surveys is 0.04 ha. If it is circular, this plot has a radius of 11.28 m.

A commonly used formula to calculate sampling intensity is:

SI % = AS (ha)/AR (ha) X 100 %

where: SI % = sampling intensity in percent
AS = total area to be sampled, in hectares (i.e., total area of sample plots)
AR = total area represented by the sample, in hectares (i.e. total area of woodlot)

An example *(from Making Cents out of Forest Inventories):*

The circular 0.04 hectare sample plot will be used to sample a woodlot of 5 hectares in area with a sampling intensity of 5 %. Use the formula from above,

5 % = AS (ha)/4 (ha) X 100 %
to derive AS (ha) = 0.25 ha/0.04 ha
= the total area to be sampled

Take this result and divide it by the area of 1 plot (0.04 ha) to get the number of required plots, always rounding up (i.e., 0.25 ha/0.04 ha = 6.25 plots, rounded up to 7 plots required to provide slightly higher than a 5 % sampling intensity).

There are several ways to locate the sample plots. Normally plots are placed at equal distances along lines across the site (i.e., transects), with equal distances between the lines in a layout designed to cover the entire forested area. Usually the distances between plots and lines are equal, but they can vary.

To calculate plot and line intervals, the amount of forest represented by one sample plot is required and is the product of the plot and line intervals.

Using the above example with 5 % sampling intensity and 0.04 ha plots:

5 % (or 0.05) = 0.04 (ha)/ AR (ha) X 100 % and re-arranging this to get
AR (ha) = 0.04 ha/ 0.05 = 0.8 ha or 1 plot is 0.80 ha or 8000 m^2

If the line interval were to equal the plot interval, the value would be the square root of 8000 m^2 which is 89.44 m, an inconvenient distance. However this could be reduced to 80 m for the plot interval and 100 m for the line interval (80 m X 100 m = 8000 m^2).

On a map, a line starting from an area boundary such as a road and running through the center of the forested area is drawn. A second line is placed at right angles to the first line at the middle of the stand. Other lines can be offset from these two lines at the required distance to create a grid and sample plots are placed at the line intersections. Wherever possible, it is preferable that these cruise lines run against the contour lines (i.e., up and down hills rather than along ridges).

Plot centers should be marked with small stakes or flagging tape and fixed area sample plots should be clearly demarcated to ensure accurate data collection.

Step 5: Collecting data

At the center of each plot, suggested measurements/calculations for the plot include:

- basal area per hectare (BA) by species, to help interpret the composition and density of trees in the stand
- soil depth, texture, and moisture regime
- descriptions of dominant understory vegetation
- significant wildlife habitats (e.g., nest, mast, or cavity trees)
- presence and description of environmentally sensitive areas (e.g., intermittent streams, seepage areas).

Within each sample plot, suggested measurements for each tree include:

- tree species
- tree diameter, measured at 1.3 m above the ground, above a specified minimum DBH (e.g., all trees greater than or equal to 10 cm in DBH)
- tree age
- tree height and/or merchantable tree length
- tree condition (e.g., stem and crown quality, presence of insects or disease). Often trees are coded as AGS or "acceptable growing stock" or UGS or "unacceptable growing stock"
- wildlife value (e.g., presence of cavity holes, stick nests, snags, conifer patches, seeps, mast trees)

Step 6: Recording data

Forest inventory tally sheets are used to record collected data accurately and legibly. See **Table C-1** entitled "Forest Inventory Tally Sheet for Fixed Area Plot Cruise" from *Making Cents out of Forest Inventories.*

Step 7: Compiling forest inventory data

Data from the tally sheets is used to create stand, stock, and estimate tables, as well height/diameter curves for each species on the site.

Step 8: Creating a stand table

A stand table converts stem counts from sample plots to estimates of the number of trees per unit area (e.g., hectare) by diameter-class. The method used depends on the type of sample unit. Using the same example from Step 4:

Woodlot size:	5 ha
Plot size:	400 m^2 (0.04 hectares)
Plot radius:	11.28 m_
Plot type:	Fixed Area
Sampling Intensity:	5 %
Number of plots to be measured:	7

Use **Table C-2** entitled "Multi Species Stand Table" to summarize all DBH data, grouped into 2 cm DBH classes, starting at the 11 cm DBH class (i.e., 10 cm to 11.99 cm). Smaller diameter DBH classes could be included but they will contribute little additional volume. Values in this table are presented only to show how data is recorded.

Use the following formula to calculate the conversion factor that will be used with fixed area plots, to convert the stem count for the plots by diameter-class to the number of trees per hectare:

$$\text{Stem count (per hectare by DBH class)} = \frac{\text{stem count (DBH class)}}{\text{number of plots}} \times \frac{1.0}{\text{plot size (ha)}}$$

$$= \frac{\text{stem count (DBH class)}}{7} \times \frac{1.0}{.04}$$

For the example described above, the conversion factor is 3.6.

To calculate the trees per hectare by DBH class, multiply each stem count for all plots by the conversion factor of 3.6, rounding values to the nearest whole tree.
(e.g., Stem count (per hectare by DBH class) = Stem count (DBH class) x 3.6)

Step 9: Creating height-diameter curves

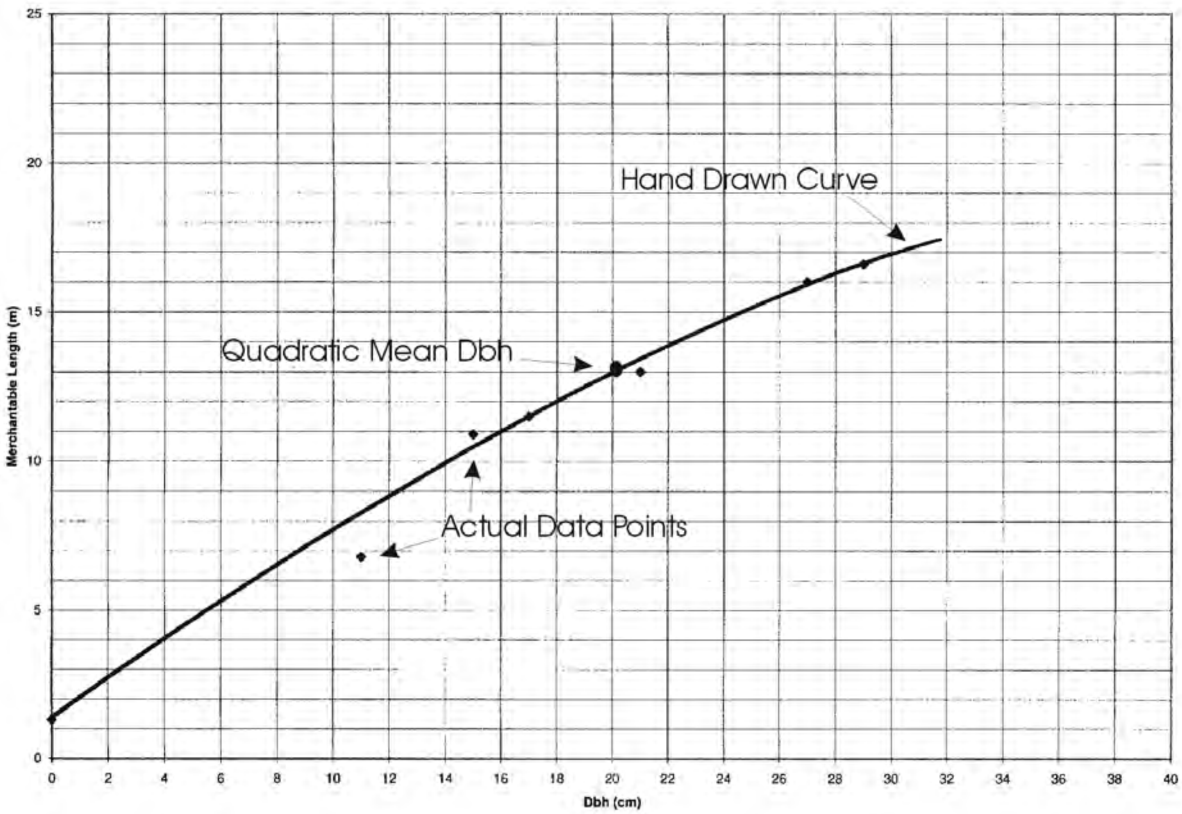
Height-diameter curves are used to calculate the volume of a particular tree species in a stand. In forest stands with numerous species and no single dominant species, height-diameter curves can still be created by combining some species.

From the sample tree data, some merchantable lengths and diameters are known, but not for all size classes found in the stand, and there is no height data for most of the trees measured for diameter. However, to estimate volume, tree heights must be estimated by deriving a height-diameter curve and using the estimated height-diameter relationships in volume equations. It is only necessary to estimate tree height for each diameter-class. The following guidelines can be used to develop a height-diameter curve:

- Record separately and by species, the merchantable lengths (or total height) and associated diameters of selected trees.
- Using standard metric graph paper, mark DBH values in cm along the x axis (horizontal) in increments of 2 cm, beginning from 0 and extending 10 cm beyond the largest tree. Mark tree height values in meters along the y axis (vertical), beginning at 0 and extending 10 meters beyond the height of the tallest tree. See **Figure C-1.**
- Mark a data point at 0 cm DBH and 1.3 m that will be the beginning of the height curve. Plot the DBH and height values for each tree.
- Draw a smooth curve through the middle of the data points, trying to assure that all data points above and below the curve are the same distance away from it.

- If unsure where to place the curve, it is preferable to draw it slightly lower than higher. Then all heights estimated from the curve will be lower, resulting in lower rather than higher volume estimates.

Figure C-1: Merchantable Length-Dbh Relationship for Hard Maple



To improve the curve, consider adding another anchor point by calculating and then plotting the Quadratic Mean Diameter (QMD). After this value is calculated, the height of a tree or trees in the stand with this DBH must be measured.

To calculate the QMD:

1. Square the DBH class value by species as shown in column (A) below to get a DBH^2 value (B) (e.g., 11 x 11=121).
2. Multiply the value in (B) by the tree count for all plots (C) for that DBH class to get the value (D) (e.g., 121 x 5= 605).
3. Add all the squared values in (D) to get the sum of the squared values (E).
4. Divide the sum of the squared values by the total number of trees used in step 2.
5. Take the square root of the value obtained in step 4, to get the QMD for hard maple.
6. Measure a sample of trees with this QMD value to find their average height.
7. Plot these coordinates (i.e., x axis value is QMD; y axis value is average tree height).

(A) DBH	(B) DBH^2	(C) Tree count for all plots	(D) DBH^2 x count for all plots
11	121	5	605
13	169	3	507
15	225	17	3825
17	289	22	6358
19	361	23	8303
21	441	31	13671
23	529	22	11638
25	625	14	8750
27	729	2	1458
29	841	3	2523
Total	**4340**	**142**	**57638 (E)**

Step 10: Creating a stock table

A stock table combines stand and volume table information to estimate timber volume per hectare. The following steps and **Table C-3** entitled "Multi Species Stock Table" provide an example of how stock tables are produced and used.

Fill out Fields #s 1-9 as outlined in **Table C-2**, the "Multi Species Stand Table."

Field # 10 of **Table C-3**- Average tree height
Record the average tree height, by species, for each diameter-class for which a volume calculation is desired. The average height of the diameter-class is required when using the Form Class 79 Table (**Table C-4**) to calculate individual tree volumes.

Field # 11- Merchantable volume per tree (m^3)
Use the Form Class 79 standard or a local volume table (**Table C-4**), to record the volume per tree (m^3). This form class table provides an estimate of gross merchantable volume for all coniferous and deciduous species.

Field # 12- Trees per hectare
Transfer these values from Field # 11 of **Table C-2**, for each species by DBH class.

Field # 13- Merchantable Volume per hectare (m^3) by DBH class for each species
To create this table, the following formula is applied to each DBH class by species:
Volume (per ha for DBH class) = tree volume (in m^3 for DBH and merchantable length) x stem count (DBH class)
Where: Tree volume = volume obtained from the Form Class 79 volume table (**Table C-4**) for the appropriate tree species and DBH class
Multiply the value recorded in Field # 11 (merchantable volume per tree in m^3) by Field # 12 (trees per hectare) and record the product.

Field # 14- Fuelwood volume per hectare
This refers to the tree tops (i.e., unmerchantable volume) that can be used for fuelwood. Since this normally represents about 80 % of the merchantable volume, the fuelwood conversion factor is 0.8.
Multiply the merchantable volume value recorded in Field # 13 by 0.8 and record the product in Field # 14.

Field # 15- Merchantable volume by DBH class for all species
Record the sum of the values recorded in Field # 13 for all species by DBH class.

Field # 16- Fuelwood volume by DBH class for all species
Record the sum of the values from Field # 14 for all species by DBH class.

Field # 17- Stems per hectare by species for all DBH classes
Record the sum of the values from Field # 12.

Field # 18- Merchantable/fuelwood volume per hectare by species
Record the sum of the values from Field # 13 to obtain the sub-total of merchantable volume per hectare by species. Do the same for Field # 14 to obtain the sub-total of fuelwood volume per hectare by species.

Field #19- Merchantable volume per hectare for species
Record the sum of the merchantable volume per hectare summed values from Field # 15.

Field # 20- Fuelwood volume per hectare for all species
Record the sum of the fuelwood volume per hectare (summed values obtained from Field # 16).

Step 11: Compiling data to create estimate tables

Table C-5, "Estimate Table for Wood Volume", and **Table C-6**, "Estimate Table for Basal Area" incorporate information from the stand and stock tables to provide estimates of wood volume and basal area respectively for the entire woodlot.

Table C-5 can be used to estimate the wood volume for the woodlot.

Field # 8- Woodlot size (ha)
Record the size the woodlot in hectares.

Field # 9- Tree species
Record both the alpha and numerical codes for each species (see **Table C-7** "Trees of Ontario"). Use more than one tally sheet when there are more than 3 tree species.

Field # 10- DBH class (cm)
The DBH classes in this table have been set at 2-cm intervals beginning with the 11-cm DBH class because trees with smaller diameters do not contribute significantly to volume calculations. DBH classes can begin at any level.

Field # 11- Merchantable volume per hectare
Transfer the values recorded in Field # 13 of **Table C-3**, the "Multi Species Stock Table" to the appropriate DBH class in **Table C-5**.

Field # 12- Merchantable volume for the woodlot
Multiply the valued recorded in Field # 11 of **Table C-5** by the woodlot size in Field # 8 and record the product.

Field # 13- Fuelwood volume per hectare
Transfer the values recorded in Field # 14 of **Table C-3** to the appropriate DBH class in **Table C-5**.

Field # 14- Fuelwood volume for the woodlot
Multiply the value recorded in Field # 13 of **Table C-5** by the woodlot size and record the product.

Field # 15- Trees per hectare
Transfer the values recorded in Field # 12 of **Table C-2**, the "Multi Species Stand Table" to the appropriate DBH class in **Table C-5.**

Field # 16- Total trees for the woodlot by DBH class by species
Multiply the value recorded in Field # 15 of **Table C-5** by the woodlot size and record the product.

Field # 17- Total merchantable volume for the woodlot by DBH class
Sum values recorded in Field # 12 of **Table C-5** for each species and record this value.

Field # 18- Total fuelwood volume for the woodlot by DBH class
Sum values recorded in Field # 14 of **Table C-5** for each species and record this value.

Field # 19- Total trees for the woodlot by DBH class
Add up the values recorded in Field # 16 of **Table C-5** for each species and record the sum.

Field # 20- Total trees for the woodlot by species (stems)
Add up the values recorded in Field # 16 of **Table C-5** for each DBH class by species and record the sum.

Field # 21- Total merchantable/fuelwood volume for the woodlot by species
Add the values recorded in Field # 12 for each DBH class by species to obtain the total merchantable volume for the woodlot by species. Also add the values recorded in Field # 14 for each DBH class by species to obtain the total fuelwood volume for the woodlot by species. Record this sum.

Field # 22- Total merchantable volume for the woodlot for all species
Add the values recorded in Field # 21 for each species to obtain the total merchantable volume for the woodlot for all species and record this sum.

Field # 23- Total fuelwood volume for the woodlot for all species
Add the values recorded in Field # 21 for each species to obtain the total fuelwood volume for the woodlot for all species and record this sum.

Field # 24- Total stems for woodlot
Add the values recorded in Field # 20 for each species to obtain the total number of trees in the woodlot. Record the sum.
Table C-6 can be used to estimate the basal area of the woodlot.

Field # 11- Basal area per tree
Record the basal area per tree for all diameter-classes found in the woodlot.

Field # 12- Trees per hectare
Transfer these values from Field # 12 in **Table C-3**.

Field # 13- Basal area per hectare
Multiply each basal area per tree value recorded in Field # 11 by the trees per hectare value recorded in Field # 12 to determine the basal area per hectare for each DBH class by species. Record the product.

Field # 14- Total basal area per species for the woodlot
Multiply the basal area per hectare value recorded in Field # 13 by the total woodlot size (in hectares) recorded in Field # 8. Record the product.

Field # 15- Total basal area for the woodlot
Add all the values recorded in Field # 14 for each DBH class for all species and record this sum.

Field # 16- Basal area per hectare
Add all the values recorded in Field # 13 by DBH class and record this sum. This value is the total basal area per hectare by species.

Field # 17- Basal area for the woodlot
Add all the values recorded in Field # 14 by DBH class and record this sum. This value is the total basal area by species for the woodlot.

Field # 18- Total basal area per hectare
Add all the values recorded in Field # 16 and record this sum. This value represents the total basal area for all species per hectare.

Field # 19- Total basal area for the woodlot
Add all the values recorded in Field # 17 and record this sum. This value represents the total basal area for all species for the entire woodlot.

Table C-1: Forest Inventory Tally Sheet for Fixed Area Plot Cruise

Location:	**1**	**Plot Radius (m):**	**6**
Base Map Number:	**2**	**Plot Size (m^2):**	**7**
Stand Number:	**3**	**Plot Number:**	**8**
Date:	**4**	**Line Number:**	**9**
Crew Members:	**5**		

					Tree Height			
Tree No.	**Tree Species Code**	**DBH (CM)**	**AGS or UGS**	**Tree Age**	**Number of Logs**	**Merch. Length**	**Total Height**	**Tree Regeneration**
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
								Species (11)
								Species (11)
								Species (11)
								Species (11)

NOTES: 19

Table C-2: Multi Species Stand Table

Location: (1) Hughes Woodlot
Date: (2) 06/18/97
Completed by: (3) Vern Gibble

Plot radius: (4) 11.28 m
Plot size: (5) 400 m 2
Number of plots: (6) 7 plots
Conversion factor: (7) 3.6

Stem Densities

	Tree Species Mh - 30 (8)		Tree Species Or - 41 (8)		Tree Species Pw - 01 (8)		
Dbh Class (cm)	Count for all plots	Trees per ha	Count for all plots	Trees per ha	Count for all plots	Trees per ha	Subtotals per ha
9	10	11	10	11	10	11	12
11	5	18					18
13	3	11					11
15	17	61	2	7			68
17	22	79	3	11			90
19	23	83	7	25	1	4	112
21	14	50	12	43	3	11	104
23	6	22	11	40	3	11	73
25	14	50	4	14	7	25	89
27	2	7	8	29	4	14	50
29	3	11	7	25	2	7	43
31			3	11	5	18	29
33			5	18	2	7	25
35			2	7			7
37							
39					1	4	4
41							
43							
45							
47					1	4	4
49							
51							
53							
55							
57							
59							
61							
							15
Count-13	109		64		29		202
Totals-14		392		230		105	727
							16

Table C-3: Multi Species Stock Table

Location:	(1) Hughes Woodlot	Plot radius	(4) 11.28 m
Date:	(2) 06/18/97	Plot size:	(5) 400 m2
Completed by:	(3) Vern Gibble	Number of plots:	(6) 7 plots
		Conversion factor:	(7) 3.6

Stem Densities

Subtotals (m3) by dbh class for all species

Dbh Class (cm)	Average Height (m)	Merch. Volume per tree (m^3)	Trees per Hectare	Merch. Volume per ha (m^3)	Fuelwood Volume per ha (m^3)	Average Height (m)	Merch. Volume per tree (m^3)	Trees per Hectare	Merch. Volume per ha (m^3)	Fuelwood Volume per ha (m^3)	Average Height (m)	Merch. Volume per tree (m^3)	Trees per Hectare	Merch. Volume per ha (m^3)	Fuelwood Volume per ha (m^3)	Total Merch. Volume (m^3)	Total Fuelwood Volume (m^3)
		Tree Species Mh - 30 (8)					Tree Species Or - 41 (8)					Tree Species Pw - 01 (8)					
9	10	11	12	13	14	10	11	12	13	14	10	11	12	13	14	15	16
11	8.3	0.0504	18	0.9072	0.7258											0.9072	0.7258
13	9.4	0.0719	11	0.7909	0.6327											0.7909	0.6327
15	10.2	0.0982	61	5.9902	4.7922	11.2	0.1007	7	0.7049	0.5639						6.6951	5.3561
17	11.5	0.1299	79	10.2621	8.2097	12.1	0.1336	11	1.4696	1.1757						11.7317	9.3854
19	12.4	0.1766	83	14.6578	11.7262	13.3	0.2031	25	5.0775	4.0620	10.4	0.1599	4	0.6396	0.5117	20.3749	16.2999
21	13.2	0.2375	50	11.875	9.5000	14.4	0.2477	43	10.6511	8.5209	11.2	0.2132	11	2.3452	1.8762	24.8713	19.8970
23	14.3	0.3003	22	6.6066	5.2853	14.8	0.3117	40	12.4680	9.9744	12.3	0.2731	11	3.0041	2.4033	22.0787	17.6630
25	15	0.3722	50	18.61	14.8880	15.1	0.3722	14	5.2108	4.1686	12.9	0.3422	25	8.5550	6.8440	32.3758	25.9006
27	16	0.4679	7	3.2753	2.6202	15.9	0.4679	29	13.5691	10.8553	13.2	0.4016	14	5.6224	4.4979	22.4668	17.9734
29	16.5	0.5599	11	6.1589	4.9271	16.2	0.5418	25	13.5450	10.8360	14.0	0.4887	7	3.4209	2.7367	23.1248	18.4998
31						17.3	0.6447	11	7.0917	5.6734	15.2	0.5862	18	10.5516	8.4413	17.6433	14.1146
33						18.2	0.7601	18	13.6818	10.9454	16.4	0.7121	7	4.9847	3.9878	18.6665	14.9332
35						18.1	0.8609	7	6.0263	4.8210						6.0263	4.8210
37																	
39											18.3	0.9700	4	3.8800	3.1040	3.8800	3.1040
41																	
43																	
45																	
47											19.9	1.7032	4	6.8128	5.4502	6.8128	5.4502
49																	
51																	
53																	
55																	
57																	
59																	
61																	
Stems-**17**			392					230					105				
Volume-**18**				79.1340	63.3072				89.4958	71.5966				49.8163	39.8530	218.4461	174.7569
																19	20

Table C-4: Form Class 79

DBH	Merchantable Length (m)																		
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10	0.0100	0.0100	0.0200	0.0200	0.0301	0.0305	0.0413	0.0420	0.0429	0.0438	0.0448	0.0574	0.0588	0.0603	0.0597	0.0612	0.0628	0.0645	0.0663
11	0.0122	0.0122	0.0244	0.0244	0.0368	0.0372	0.0504	0.0514	0.0525	0.0537	0.0550	0.0705	0.0723	0.0742	0.0735	0.0754	0.0774	0.0796	0.0820
12	0.0144	0.0144	0.0288	0.0288	0.0434	0.0439	0.0596	0.0608	0.06212	0.0636	0.0652	0.0835	0.0858	0.0881	0.0872	0.0895	0.0921	0.0948	0.0977
13	0.0170	0.0170	0.0340	0.0340	0.0513	0.0519	0.0704	0.0719	0.0735	0.0754	0.0773	0.0991	0.1019	0.1048	0.1037	0.1065	0.1096	0.1130	0.1166
14	0.0196	0.0196	0.0392	0.0392	0.0591	0.0599	0.0812	0.0830	0.08495	0.0871	0.0894	0.1148	0.1180	0.1215	0.1201	0.1235	0.1272	0.1312	0.1355
15	0.0226	0.0226	0.0452	0.0452	0.0682	0.0691	0.0938	0.0959	0.0982	0.1007	0.1035	0.1329	0.1368	0.1409	0.1393	0.1434	0.1478	0.1525	0.1577
16	0.0256	0.0256	0.0512	0.0512	0.0772	0.0783	0.1063	0.1087	0.11141	0.1144	0.1175	0.1511	0.1556	0.1604	0.1586	0.1632	0.1684	0.1739	0.1799
17	0.0290	0.0290	0.0580	0.0580	0.0875	0.0887	0.1205	0.1233	0.1265	0.1299	0.1336	0.1718	0.1771	0.1826	0.1805	0.1860	0.1920	0.1984	0.2054
18	0.0324	0.0324	0.0648	0.0648	0.0978	0.0992	0.1348	0.1379	0.1415	0.1454	0.1496	0.1926	0.1986	0.2049	0.2025	0.2087	0.2156	0.2230	0.2310
19	0.0358	0.0456	0.0716	0.0814	0.1073	0.1167	0.1425	0.1514	0.1599	0.1688	0.1766	0.2031	0.2106	0.2177	0.2248	0.2312	0.2374	0.2432	0.2487
20	0.0392	0.0588	0.0784	0.0980	0.1169	0.1343	0.1503	0.1649	0.1782	0.1922	0.2035	0.2137	0.2226	0.2304	0.2471	0.2537	0.2591	0.2634	0.2665
21	0.0433	0.0650	0.0867	0.1083	0.1292	0.1485	0.1662	0.1825	0.1973	0.2132	0.2260	0.2375	0.2477	0.2566	0.2750	0.2827	0.2890	0.2941	0.2980
22	0.0474	0.0712	0.0949	0.1186	0.1415	0.1626	0.1821	0.2000	0.2163	0.2341	0.2484	0.2612	0.2727	0.2828	0.3029	0.3116	0.3189	0.3248	0.3294
23	0.0520	0.0780	0.1039	0.1299	0.1550	0.1782	0.1996	0.2192	0.2372	0.2572	0.2731	0.2874	0.3003	0.3117	0.3337	0.3436	0.3519	0.3588	0.3643
24	0.0565	0.0847	0.1129	0.1412	0.1684	0.1937	0.2170	0.2384	0.2581	0.2802	0.2977	0.3136	0.3279	0.3406	0.3644	0.3755	0.3849	0.3927	0.3991
25	0.0614	0.0921	0.1227	0.1535	0.1831	0.2106	0.2360	0.2593	0.2808	0.3053	0.3246	0.3422	0.3580	0.3722	0.3980	0.4104	0.4210	0.4300	0.4373
26	0.0663	0.0994	0.1325	0.1657	0.1977	0.2274	0.2549	0.2802	0.3035	0.3304	0.3515	0.3707	0.3881	0.4038	0.4315	0.4453	0.4571	0.4672	0.4755
27	0.0716	0.1074	0.1431	0.1789	0.2135	0.2456	0.2754	0.3028	0.3280	0.3576	0.3806	0.4016	0.4208	0.4381	0.4679	0.4832	0.4964	0.5077	0.5171
28	0.0769	0.1153	0.1537	0.1921	0.2292	0.2637	0.2958	0.3253	0.3525	0.3847	0.4097	0.4325	0.4534	0.4724	0.5043	0.5210	0.5356	0.5481	0.5587
29	0.0826	0.1238	0.1651	0.2064	0.2462	0.2833	0.3178	0.3496	0.3789	0.4140	0.4411	0.4659	0.4887	0.5095	0.5418	0.5599	0.5757	0.5895	0.6013
30	0.0882	0.1323	0.1765	0.2206	0.2632	0.3029	0.3398	0.3739	0.4053	0.4432	0.4724	0.4993	0.5240	0.5465	0.5793	0.5987	0.6158	0.6309	0.6439
31	0.0943	0.1415	0.1887	0.2358	0.2814	0.3239	0.3635	0.4001	0.4339	0.4746	0.5060	0.5351	0.5618	0.5862	0.6232	0.6447	0.6636	0.6803	0.6948
32	0.1004	0.1506	0.2008	0.2510	0.2996	0.3449	0.3871	0.4263	0.4625	0.5059	0.5396	0.5708	0.5996	0.6259	0.6671	0.6906	0.7114	0.7297	0.7456
33	0.1069	0.1603	0.2138	0.2672	0.3189	0.3673	0.4124	0.4543	0.4931	0.5393	0.5754	0.6089	0.6399	0.6683	0.7121	0.7375	0.7601	0.7800	0.7974
34	0.1133	0.1700	0.2267	0.2833	0.3382	0.3896	0.4376	0.4822	0.5237	0.5726	0.6112	0.6470	0.6802	0.7107	0.7570	0.7843	0.8087	0.8303	0.8491
35	0.1202	0.1803	0.2404	0.3005	0.3587	0.4133	0.4644	0.5119	0.5561	0.6081	0.6493	0.6876	0.7231	0.7558	0.8052	0.8346	0.8609	0.8843	0.9048
36	0.1271	0.1906	0.2541	0.3176	0.3792	0.4370	0.4911	0.5415	0.5884	0.6435	0.6873	0.7281	0.7659	0.8009	0.8533	0.8848	0.9130	0.9382	0.9604
37	0.1344	0.2015	0.2686	0.3358	0.4009	0.4620	0.5192	0.5726	0.6223	0.6810	0.7276	0.7711	0.8114	0.8488	0.9057	0.9396	0.9700	0.9973	1.0214
38	0.1416	0.2123	0.2831	0.3539	0.4225	0.4870	0.5473	0.6037	0.6561	0.7185	0.7679	0.8140	0.8569	0.8966	0.9581	0.9943	1.0270	1.0563	1.0824
39	0.1493	0.2238	0.2984	0.3730	0.4454	0.5133	0.5770	0.6364	0.6918	0.7581	0.8103	0.8590	0.9042	0.9461	1.0136	1.0523	1.0874	1.1189	1.1470
40	0.1569	0.2353	0.3137	0.3921	0.4682	0.5396	0.6066	0.6691	0.7274	0.7976	0.8526	0.9039	0.9515	0.9956	1.0690	1.1103	1.1477	1.1814	1.2116
41	0.1649	0.2474	0.3298	0.4122	0.4922	0.5674	0.6380	0.7039	0.7654	0.8393	0.8975	0.9520	1.0027	1.0499	1.1262	1.1700	1.2098	1.2458	1.2781
42	0.1729	0.2594	0.3459	0.4323	0.5162	0.5952	0.6693	0.7386	0.8033	0.8810	0.9424	1.0000	1.0539	1.1041	1.1833	1.2297	1.2719	1.3102	1.3446
43	0.1814	0.2721	0.3628	0.4534	0.5415	0.6244	0.7023	0.7752	0.8433	0.9248	0.9895	1.0502	1.1070	1.1601	1.2428	1.2919	1.3366	1.3772	1.4138
44	0.1898	0.2847	0.3796	0.4745	0.5667	0.6536	0.7352	0.8117	0.8833	0.9685	1.0365	1.1003	1.1601	1.2160	1.3023	1.3540	1.4012	1.4441	1.4829
45	0.1986	0.2980	0.3973	0.4966	0.5931	0.6841	0.7697	0.8500	0.9252	1.0143	1.0857	1.1528	1.2158	1.2746	1.3646	1.4191	1.4689	1.5143	1.5554
46	0.2074	0.3112	0.4149	0.5186	0.6194	0.7146	0.8042	0.8883	0.9671	1.0600	1.1349	1.2053	1.2714	1.3332	1.4269	1.4841	1.5366	1.5844	1.6278
47	0.2167	0.3250	0.4333	0.5417	0.6470	0.7465	0.8403	0.9283	1.0109	1.1079	1.1864	1.2603	1.3296	1.3946	1.4921	1.5522	1.6073	1.6576	1.7032
48	0.2259	0.3388	0.4517	0.5647	0.6746	0.7784	0.8763	0.9683	1.0547	1.1558	1.2379	1.3152	1.3878	1.4559	1.5572	1.6202	1.6779	1.7307	1.7786
49	0.2355	0.3532	0.4710	0.5887	0.7033	0.8116	0.9139	1.0101	1.1004	1.2057	1.2916	1.3725	1.4486	1.5199	1.6252	1.6912	1.7517	1.8071	1.8573
50	0.2451	0.3676	0.4902	0.6127	0.7320	0.8448	0.9514	1.0518	1.1461	1.2556	1.3452	1.4297	1.5093	1.5839	1.6931	1.7621	1.8255	1.8834	1.9360
51	0.2655	0.3982	0.5310	0.6637	0.7930	0.9154	1.0312	1.1405	1.2433	1.3617	1.4593	1.5515	1.6385	1.7202	1.8402	1.9157	1.9852	2.0489	2.1070

Table C-4 *continued*

Form Class 79

DBH (cm)	Merchantable Length (m) 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
54	0.2859	0.4288	0.5717	0.7147	0.8540	0.9860	1.1110	1.2291	1.3404	1.4678	1.5734	1.6733	1.7676	1.8564	1.9872	2.0692	2.1449	2.2144	2.2779
55	0.2967	0.4450	0.5933	0.7417	0.8863	1.0234	1.1533	1.2760	1.3918	1.5241	1.6340	1.7380	1.8362	1.9288	2.0654	2.1510	2.2300	2.3026	2.3691
56	0.3074	0.4612	0.6149	0.7686	0.9185	1.0607	1.1955	1.3229	1.4431	1.5803	1.6945	1.8026	1.9048	2.0011	2.1436	2.2327	2.3150	2.3907	2.4602
57	0.3186	0.4780	0.6373	0.7966	0.9519	1.0994	1.2393	1.3716	1.4965	1.6397	1.7585	1.8710	1.9774	2.0776	2.2222	2.3146	2.4001	2.4788	2.5511
58	0.3298	0.4947	0.6596	0.8245	0.9853	1.1381	1.2830	1.4202	1.5498	1.6990	1.8225	1.9394	2.0499	2.1540	2.3007	2.3964	2.4851	2.5669	2.6420
59	0.3414	0.5121	0.6827	0.8534	1.0199	1.1782	1.3283	1.4706	1.6050	1.7605	1.8889	2.0103	2.1251	2.2333	2.3820	2.4812	2.5732	2.6581	2.7361
60	0.3529	0.5294	0.7058	0.8823	1.0545	1.2182	1.3736	1.5209	1.6601	1.8220	1.9552	2.0812	2.2003	2.3126	2.4632	2.5659	2.6612	2.7493	2.8302
61	0.3649	0.5474	0.7298	0.9122	1.0903	1.2596	1.4205	1.5730	1.7172	1.8851	2.0231	2.1538	2.2774	2.3939	2.5493	2.6559	2.7549	2.8465	2.9308
62	0.3768	0.5653	0.7537	0.9421	1.1260	1.3010	1.4673	1.6250	1.7743	1.9481	2.0910	2.2264	2.3544	2.4751	2.6353	2.7459	2.8486	2.9436	3.0313
63	0.3892	0.5838	0.7784	0.9730	1.1630	1.3438	1.5158	1.6789	1.8334	2.0127	2.1605	2.3006	2.4332	2.5582	2.7264	2.8413	2.9482	3.0472	3.1385
64	0.4015	0.6023	0.8031	1.0039	1.1999	1.3866	1.5642	1.7327	1.8924	2.0772	2.2300	2.3748	2.5119	2.6413	2.8174	2.9367	3.0477	3.1507	3.2457
65	0.4143	0.6215	0.8286	1.0358	1.2381	1.4308	1.6141	1.7882	1.9533	2.1438	2.3017	2.4514	2.5932	2.7271	2.9115	3.0353	3.1507	3.2577	3.3566
66	0.4270	0.6406	0.8541	1.0676	1.2762	1.4749	1.6640	1.8437	2.0141	2.2103	2.3734	2.5280	2.6745	2.8129	3.0056	3.1339	3.2536	3.3647	3.4675
67	0.4402	0.6603	0.8804	1.1005	1.3155	1.5205	1.7156	1.9010	2.0769	2.2804	2.4490	2.6088	2.7603	2.9034	3.0996	3.2323	3.3561	3.4711	3.5777
68	0.4533	0.6800	0.9066	1.1333	1.3548	1.5660	1.7671	1.9583	2.1397	2.3504	2.5245	2.6896	2.8460	2.9938	3.1936	3.3306	3.4585	3.5775	3.6878
69	0.4669	0.7003	0.9337	1.1671	1.3952	1.6129	1.8201	2.0173	2.2044	2.4225	2.6023	2.7729	2.9344	3.0870	3.2904	3.4319	3.5641	3.6872	3.8013
70	0.4804	0.7205	0.9607	1.2009	1.4356	1.6597	1.8731	2.0762	2.2691	2.4946	2.6801	2.8561	3.0228	3.1802	3.3871	3.5332	3.6696	3.7968	3.9148
71	0.4943	0.7414	0.9886	1.2357	1.4773	1.7079	1.9277	2.1369	2.3357	2.5682	2.7595	2.9410	3.1129	3.2753	3.4868	3.6375	3.7782	3.9095	4.0314
72	0.5082	0.7623	1.0164	1.2705	1.5189	1.7561	1.9823	2.1976	2.4023	2.6418	2.8388	3.0258	3.2029	3.3703	3.5864	3.7417	3.8868	4.0222	4.1480
73	0.5225	0.7838	1.0451	1.3063	1.5618	1.8058	2.0385	2.2601	2.4708	2.7168	2.9196	3.1122	3.2946	3.4671	3.6889	3.8489	3.9984	4.1379	4.2675
74	0.5368	0.8052	1.0737	1.3421	1.6046	1.8554	2.0946	2.3225	2.5393	2.7918	3.0004	3.1985	3.3862	3.5639	3.7914	3.9560	4.1099	4.2535	4.3869
75	0.5515	0.8273	1.1031	1.3789	1.6486	1.9064	2.1523	2.3867	2.6097	2.8689	3.0834	3.2872	3.4804	3.6634	3.8967	4.0661	4.2246	4.3724	4.5097
76	0.5662	0.8494	1.1325	1.4156	1.6925	1.9573	2.2099	2.4508	2.6801	2.9459	3.1664	3.3759	3.5746	3.7628	4.0020	4.1762	4.3392	4.4912	4.6325
77	0.5813	0.8721	1.1627	1.4534	1.7377	2.0096	2.2692	2.5167	2.7524	3.0265	3.2535	3.4692	3.6740	3.8679	4.1149	4.2948	4.4633	4.6205	4.7667
78	0.5964	0.8947	1.1929	1.4911	1.7829	2.0619	2.3284	2.5826	2.8247	3.1070	3.3405	3.5625	3.7733	3.9730	4.2277	4.4134	4.5873	4.7497	4.9009
79	0.6119	0.9179	1.2239	1.5298	1.8292	2.1156	2.3892	2.6502	2.8989	3.1898	3.4301	3.6586	3.8756	4.0813	4.3441	4.5359	4.7155	4.8834	5.0398
80	0.6274	0.9411	1.2548	1.5685	1.8755	2.1692	2.4499	2.7178	2.9730	3.2726	3.5196	3.7546	3.9778	4.1896	4.4605	4.6583	4.8437	5.0171	5.1787
81	0.6433	0.9650	1.2866	1.6082	1.9230	2.2243	2.5123	2.7872	3.0491	3.3570	3.6107	3.8523	4.0819	4.2997	4.5790	4.7828	4.9739	5.1527	5.3195
82	0.6592	0.9888	1.3184	1.6479	1.9705	2.2793	2.5746	2.8565	3.1252	3.4413	3.7018	3.9500	4.1859	4.4098	4.6974	4.9072	5.1040	5.2883	5.4602
83	0.6755	1.0132	1.3510	1.6886	2.0192	2.3358	2.6385	2.9276	3.2033	3.5268	3.7941	4.0489	4.2913	4.5215	4.8161	5.0317	5.2341	5.4235	5.6003
84	0.6917	1.0376	1.3835	1.7293	2.0679	2.3922	2.7023	2.9986	3.2813	3.6123	3.8864	4.1477	4.3966	4.6331	4.9347	5.1562	5.3641	5.5586	5.7403
85	0.7084	1.0626	1.4168	1.7710	2.1178	2.4500	2.7678	3.0714	3.3612	3.6998	3.9809	4.2490	4.5045	4.7475	5.0563	5.2838	5.4973	5.6972	5.8838
86	0.7251	1.0876	1.4501	1.8126	2.1676	2.5077	2.8332	3.1442	3.4410	3.7873	4.0753	4.3503	4.6124	4.8619	5.1779	5.4113	5.6305	5.8357	6.0272
87	0.7422	1.1132	1.4842	1.8553	2.2187	2.5671	2.9006	3.2196	3.5241	3.8786	4.1740	4.4562	4.7252	4.9815	5.3045	5.5442	5.7694	5.9803	6.1772
88	0.7592	1.1388	1.5183	1.8979	2.2698	2.6264	2.9680	3.2949	3.6072	3.9698	4.2726	4.5620	4.8380	5.1010	5.4310	5.6771	5.9082	6.1248	6.3272
89	0.7767	1.1650	1.5532	1.9416	2.3221	2.6872	3.0370	3.3720	3.6922	4.0634	4.3739	4.6706	4.9537	5.2236	5.5612	5.8137	6.0510	6.2735	6.4815
90	0.7941	1.1911	1.5881	1.9852	2.3743	2.7479	3.1060	3.4490	3.7771	4.1569	4.4751	4.7792	5.0694	5.3461	5.6913	5.9503	6.1938	6.4222	6.6358
91	0.8120	1.2179	1.6238	2.0298	2.4278	2.8099	3.1764	3.5276	3.8636	4.2526	4.5787	4.8904	5.1881	5.4719	5.8237	6.0893	6.3392	6.5737	6.7932
92	0.8298	1.2446	1.6595	2.0744	2.4812	2.8719	3.2468	3.6061	3.9500	4.3482	4.6822	5.0016	5.3067	5.5977	5.9561	6.2283	6.4846	6.7252	6.9506
93	0.8480	1.2720	1.6960	2.1200	2.5358	2.9352	3.3184	3.6859	4.0376	4.4461	4.7883	5.1157	5.4287	5.7273	6.0897	6.3688	6.6318	6.8790	7.1107
94	0.8662	1.2993	1.7325	2.1656	2.5903	2.9984	3.3900	3.7656	4.1252	4.5440	4.8944	5.2298	5.5506	5.8569	6.2232	6.5093	6.7790	7.0328	7.2707
95	0.8849	1.3273	1.7698	2.2122	2.6460	3.0630	3.4632	3.8471	4.2147	4.6441	5.0028	5.3465	5.6753	5.9894	6.3597	6.6529	6.9295	7.1900	7.4344
96	0.9035	1.3552	1.8070	2.2587	2.7017	3.1275	3.5364	3.9285	4.3041	4.7441	5.1112	5.4631	5.7999	6.1219	6.4961	6.7965	7.0800	7.3471	7.5981
97	0.9225	1.3838	1.8450	2.3063	2.7587	3.1937	3.6115	4.0124	4.3965	4.8447	5.2200	5.5798	5.9244	6.2541	6.6374	6.9449	7.2355	7.5094	7.7670
98	0.9415	1.4123	1.8830	2.3538	2.8156	3.2598	3.6866	4.0962	4.4889	4.9452	5.3287	5.6965	6.0489	6.3862	6.7786	7.0933	7.3909	7.6716	7.9359
99	0.9609	1.4414	1.9219	2.4023	2.8738	3.3274	3.7634	4.1821	4.5836	5.0475	5.4391	5.8150	6.1753	6.5203	6.9238	7.2460	7.5509	7.8386	8.1097
100	0.9803	1.4705	1.9607	2.4508	2.9319	3.3949	3.8401	4.2679	4.6783	5.1497	5.5495	5.9334	6.3016	6.6543	7.0690	7.3987	7.7108	8.0056	8.2835

Source: Appendix C "Sugar Bush Management for Maple Syrup Production", 1987, C.Coons

Table C-5: Estimate Table For Wood Volume

Location:	(1) Hughes Woodlot	Plot Size:	(5) 400 m2
Date:	(2) 06/21/97	Number of Plots:	(6) 7 plots
Completed by:	(3) Vern Gibble	Conversion Factor:	(7) 3.6
Plot Radius:	(4) II.28m	Woolot Size (ha):	(8) 4 ha

	Tree Species - 9																		Woodlot Totals		
	Mh-30						Or-41						Pw -01								
Dbh Class (cm)	Merch. Volume per ha (m^3)	Merch. Volume Woodlot (m^3)	Fuelwood Volume per ha (m^3)	Fuelwood Volume Woodlot (m^3)	Trees per ha	Total Mh Trees	Merch. Volume per ha (m^3)	Merch. Volume Woodlot (m^3)	Fuelwood Volume per ha (m^3)	Fuelwood Volume Woodlot (m^3)	Trees per ha	Total Or Trees	Merch. Volume per ha (m^3)	Merch. Volume Woodlot (m^3)	Fuelwood Volume per ha (m^3)	Fuelwood Volume Woodlot (m^3)	Trees per ha	Total Pw Trees	Total Merch. Volume Woodlot	Total Fuelwood Volume Woodlot	Total Trees Woodlot
10	11	12	13	14	15	16	11	12	13	14	15	16	11	12	13	14	15	16	17	18	19
11	0.9072	3.6288	0.7258	2.9030	18	72													3.6	2.9	72
13	0.7909	3.1636	0.6327	2.5309	11	44													3.2	2.5	44
15	5.9902	23.9608	4.7922	19.1686	61	244	0.7049	2.8196	0.5639	2.2557	7	28							26.8	21.4	272
17	10.2621	41.0484	8.2097	32.8387	79	316	1.4696	5.8784	1.1757	4.7027	11	44							46.9	37.5	360
19	14.6578	58.6312	11.7262	46.9050	83	332	5.0775	20.3100	4.0620	16.2480	25	100	0.6396	2.5584	0.5117	2.0467	4	16	81.5	65.2	448
21	11.8750	47.5000	9.5000	38.0000	50	200	10.6511	42.6044	8.5209	34.0835	43	172	2.3452	9.3808	1.8762	7.5046	11	44	99.5	79.6	416
23	6.6066	26.4264	5.2853	21.1411	20	80	12.4680	49.8720	9.9744	39.8976	40	160	3.0041	12.0164	2.4033	9.6131	12	48	88.3	70.7	288
25	18.6100	74.4400	14.8880	59.5520	50	200	5.2108	20.8432	4.1686	16.6746	13	52	8.5550	34.2200	6.8440	27.3760	25	100	129.5	103.6	352
27	3.2753	13.1012	2.6202	10.4810	7	28	13.5691	54.2764	10.8553	43.4211	29	116	5.6224	22.4896	4.4979	17.9917	14	56	89.9	71.9	200
29	6.1589	24.6356	4.9271	19.7085	11	44	13.5450	54.1800	10.8360	43.3440	25	100	3.4209	13.6836	2.7367	10.9469	8	32	92.5	74.0	176
31							7.0917	28.3668	5.6734	22.6934	11	44	10.5516	42.2064	8.4413	33.7651	18	72	70.6	56.5	116
33							13.6818	54.7272	10.9454	43.7818	18	72	4.9847	19.9388	3.9878	15.9510	7	28	74.7	59.7	100
35							6.0263	24.1052	4.8210	19.2842	7	28							24.1	19.3	28
37																			0.0	0.0	0
39													3.8800	15.5200	3.1040	12.4160	4	16	15.5	12.4	16
45																			0.0	0.0	0
47													6.8128	27.2512	5.4502	21.8010	4	16	27.3	21.8	16
Stems -20						1560						916						428			2904
Volume -21		316.5360		253.2288				357.9832		286.3866				199.2652		159.4122			873.8	699.0	
																			22	23	24

Table C-6: Estimate Table For Basal Area

Location:	(1) Hughes Woodlot	Plot Size:	(5) 400 m2
Date:	(2) 06/21/97	Number of Plots:	(6) 7 plots
Completed by:	(3) Vern Gibble	Conversion Factor:	(7) 3.6
Plot Radius:	(4) II.28m	Woolot Size (ha):	(8) 4 ha

	Tree Species - 9													
	Mh-30				Or-41				Pw -01					
Dbh Class (cm)	B.A. per/tree	Trees per/ha	B.A. per/ha	Tot. B.A. /species Woodlot	B.A. per/tree	Trees per/ha	B.A. per/ha	Tot. B.A. /species Woodlot	B.A. per/tree	Trees per/ha	B.A. per/ha	Tot. B.A. /species Woodlot	Total B.A. Woodlot	
10	11	12	13	14	11	12	13	14	11	12	13	14	15	
11	0.0100	18	0.1800	0.7200									0.72	
13	0.0130	11	0.1430	0.5720									0.57	
15	0.0180	61	1.0980	4.3920	0.0180	7	0.1260	0.5040					4.90	
17	0.0230	79	1.8170	7.2680	0.0230	11	0.2530	1.0120					8.28	
19	0.0280	83	2.3240	9.2960	0.0280	25	0.7000	2.8000	0.0280	4	0.1120	0.448	12.54	
21	0.0350	50	1.7500	7.0000	0.0350	43	1.5050	6.0200	0.0350	11	0.3850	1.540	14.56	
23	0.0420	20	0.8400	3.3600	0.0420	40	1.6800	6.7200	0.0420	12	0.5040	2.016	12.10	
25	0.0490	50	2.4500	9.8000	0.0490	13	0.6370	2.5480	0.0490	25	1.2250	4.900	17.25	
27	0.0570	7	0.3990	1.5960	0.0570	29	1.6530	6.6120	0.0570	14	0.7980	3.192	11.40	
29	0.0660	11	0.7260	2.9040	0.0660	25	1.6500	6.6000	0.0660	8	0.5280	2.112	11.62	
31					0.0750	11	0.8250	3.3000	0.0750	18	1.3500	5.400	8.70	
33					0.0860	18	1.5480	6.1920	0.0860	7	0.6020	2.408	8.60	
35					0.0960	7	0.6720	2.6880						
37														
39									0.1190	4	0.4760	1.904	1.90	
45														
47									0.1730	4	0.6920	2.768	2.77	
B.A/ha - **16**			11.7270				11.2490				6.6720		29.65	**18**
B.A/woodlot - **17**				46.9080				44.9960				26.688	115.90	**19**

Table C-7: Tree Species of Ontario				
Numeric	**Alpha**	**Common Name**	**Genus**	**Species**
45	Ab	Ash, black	Fraxinus	nigra
132	Aq	Ash, blue	Fraxinus	quadrangulata
146		Mountain-ash, European	Sorbus	aucuparia
176	AP	Ash, pumpkin	Fraxinus	profunda
47	Ag	Ash, red (green ash)	Fraxinus	pennsylvanica
46	Aw	Ash, white	Fraxinus	americana
70	Al	Aspen, large tooth	Populus	grandidentata
74	At	Aspen, trembling	Populus	tremuloides
51	Bd	Basswood	Tilia	americana
44	Be	Beech, American	Fagus	grandifolia
111	Bu	Beech, blue	Carpinus	caroliniana
112	Bc	Birch, cherry, sweet	Betula	lenta
120	Bp	Birch, European whtie (weeping or silver)	Betula	pendula
168	Br	Birch, grey or wire	Betula	populifolia
121		Birch, hairy or swamp	Betula	pubescens
38	Bw	Birch, white (paper birch)	Betula	papyrifera
37	By	Birch, yellow	Betula	alleghaniensis
137		Black gum	Nyssa	sylvatica
73	Rf	Buckthorn, glossy, alder	Rhamnus	frangula
55	Bn	Butternut	Juglans	cinerea
77		Catalapa, northern, Indian bean	Catalpa	speciosa
23	Cr	Cedar, eastern red	Juniperus	virginiana
109		Cedar, western red	Thuja	plicata
22	Cw	Cedar, white	Thuja	occidentalis
58	Cb	Cherry, black	Prunus	serotina
90	Cm	Cherry, mazzard (sweet cherry)	Prunus	avium
139		Cherry, pin	Prunus	pensylvanica
174	Cc	Cherry, sour'	Prunus	cerasus
171	Cd	Chestnut, American	Castanea	dentata
69	Hc	Chestnut, horse	Aesculus	hippocastanum
172	Cs	Chestnut, sweet	Castanea	sativa
71	Pd	Cottonwood	Populus	deltoides
136		Cucumber tree	Magnolia	acuminata
50	Ea	Elm, American	Ulmus	americana
170	Es	Elm, red (slippery)	Ulmus	rubra
169	Eu	Elm, rock	Ulmus	thomasii
20	Bf	Fir, balsam	Abies	balsamea
68	Hk	Hackberry	Celtis	occidentalis
128	Ht	Hawthorn	Crataegus	spp.
19	He	Hemlock, eastern	Tsuga	canadensis
93	Hl	Hickory, big shellbark	Carya	laciniosa
123	Hb	Hickory, bitternut	Carya	cordiformis
92	Hm	Hickory, mockernut	Carya	tomentosa
89	Hp	Hickory, pignut	Carya	glabra
124	Hs	Hickory, shagbark	Carya	ovata
141		Hop tree	Ptelea	trifoliata

Table C-7: Tree Species of Ontario continued

Numeric	Alpha	Common Name	Genus	Species
56	Id	Ironwood	Ostrya	virginiana
133	Kk	Kentucky coffee tree	Gymnocladus	dioicus
26	Le	Larch, european	Larix	decidua
27	Lj	Larch, Japanese	Larix	leptolepis
166	Bl	Linden, big leaf	Tilia	platyphyllos
150	Ll	Linden, little leaf	Tilia	cordata
61	Lb	Locust, black	Robinia	psuedoacacia
96	Gt	Locust, honey	Gleditsia	triacanthos
94	Mb	Maple, black (hard)	Acer	nigrum
117	Mm	Maple, Manitoba (box elder)	Acer	negundo
34	Mn	Maple, norway	Acer	platanoides
32	Mr	Maple, red (soft)	Acer	rubrum
33	Ms	Maple, silver (soft)	Acer	saccharinum
30	Mh	Maple, sugar (hard)	Acer	saccharum
175	Mo	Mulberry, red	Morus	rubra
86	Obl	Oak, black	Quercus	velutina
42	Ob	Oak, bur (mossy cup oak)	Quercus	macrocarpa
91	Oc	Oak, chinquapin	Quercus	muehlenbergii
87	Op	Oak, pin	Quercus	palustris
41	Or	Oak, red	Quercus	rubra
39	Os	Oak, Shumard	Quercus	shumardii
88	Osw	Oak, swamp white	Quercus	bicolor
40	Ow	Oak, white	Quercus	alba
119		Pawpaw	Asimina	triloba
6	Pa	Pine, Austrian	Pinus	nigra
1	Pw	Pine, eastern white	Pinus	strobus
3	Pj	Pine, jack	Pinus	banskiana
5	Pp	Pine, pitch	Pinus	rigida
2	Pr	Pine, red	Pinus	resinosa
4	Ps	Pine, Scots	Pinus	sylvestris
73	Pb	Poplar, balsam	Populus	balsamifera
72	Pc	Poplar, Carolina	Populus	X canadensis
97	Ph	Poplar, hybrid	Populus	Hybrid poplar
76	Pl	Poplar, silver	Populus	alba
125		Redbud	Cercis	canadensis
78	Ss	Sassafras	Sassafras	albidum
13	Sb	Spruce, black	Picea	mariana
15	Sn	Spruce, norway	Picea	abies
14	Sr	Spruce, red	Picea	rubens
12	Sw	Spruce, white	Picea	glauca
57	Sy	Sycamore	Platanus	occidentalis
25	La	Tamarack	Larix	laricina
60	Tp	Tulip tree	Liriodendron	tulipifera
54	Wb	Walnut, black	Juglans	nigra
145		White beam tree	Sorbus	aria
64	We	Willow, weeping	Salix	babylonica
		Willow, black	Salix	nigra
		Willow, crack	Salix	fragilis
		Willow, peach-leaved	Salix	amygdaloides
		Willow, hybrid	Salix	alba X fragilis
63	Ww	Willow, white (European willow)	Salix	alba

Appendix D

A Guide to Tree Species Suitability for Site Regions 6E and 7E

American Beech
Basswood
Black Cherry
Black Walnut *
Bitternut Hickory *
Red Maple
Red Oak
Red Pine (Plantation)
Silver Maple
Sugar Maple
White Ash
White Pine (Plantation)
White Spruce (Plantation)
White Oak *

** Table only available for Site Region 7E*

INTRODUCTION

Soil and site quality assessment helps managers avoid problems often associated with the management of species that are unsuited for the existing site conditions. For example, red or white pine planted on calcareous soils can die prior to reaching rotation age. Sugar maple occurring on poorly drained soils frequently declines in vigor and may even die before reaching maturity.

DEVELOPMENT OF THE GUIDE

This guide was developed from soil and stand data from 1,160 unmanaged, **even-aged** stands (approximately 30- to 70-years-old) that were relatively free from disease and disturbance. Site and soil variables were correlated and site indices for the major commercial species were determined. The results are presented in a series of tree species suitability ("on-site") tables listing site index and productivity ratings values for these species within a framework of easily recognizable soil features.

The nine soil texture groups represent practical classes for evaluating the relative nutritional and moisture holding capacity of the soil for forest growth. The "Depth to Distinct Mottles" component of the matrix provides a simple way to evaluate available moisture supply using features that indicate the nature of the internal drainage and water table activity. "Depth to Bedrock" is directly related to the effective rooting volume. For red and white pine, the "Depth to Carbonates" and "Depth to Root-Restricting Layer" are also incorporated in the on-site matrix due to their influence on productivity, particularly on severely eroded and compacted soils respectively.

POTENTIAL APPLICATION TO NATURAL FOREST MANAGEMENT

The tables in this Appendix can be used to help the management of stands (e.g., scheduling of silvicultural operations such as thinning and pruning) by:

- ranking species performance on different site conditions
- identifying the best and poorest local site conditions, as well as potential problem sites
- predicting variation in stand performance due to local changes in soil and site quality,
- and encouraging the communication of silvicultural prescriptions and experiences using a common soil and site description framework.

Prior to site visits, managers can help to ensure that on-site sampling will be representative of the prevailing soil and site conditions by reviewing soil survey maps and reports to determine the distribution of soil and land conditions for the site. For example, variations in topography are often strongly related to changes in soil and site features. Aerial photographs and topographic maps may be useful to predict changes in soil features like texture, moisture, and depth to carbonates and root-restricting layers.

FIELD INSPECTIONS

During field inspections, it is preferable to obtain at least one field determination of site features from each prominent site position in the landscape, as well as a minimum of one field check per hectare. Generally homogeneous topography requires fewer checks; variable topography requires more checks. The extent of existing soil degradation on knolls and crest landscape positions should be estimated from the presence of carbonates within 50 cm of the surface and/or lighter soil colors at the surface and/or absence of surface horizons.

The procedures described below require that a copy of the following publication be available during field inspection:

> Ontario Centre for Soil Resource Evaluation. 1993. Field Manual for Describing Soils in Ontario. 4th edition. Ontario Centre for Soil Resource Evaluation. Publicaiton No. 93-1. 62 p.
>
> Copies of this manual may be obtained from: Department of Land Resource Science, University of Guelph, Guelph, Ontario N1G 2W1 or 519/824-4120 x 4359.

At each field inspection site, use the following methods to determine soil texture group, and depth to distinct mottles, carbonates, and the root-restricting layer:

1. Use a shovel to expose a face of a soil profile or use a soil auger to obtain a continuous core of the soil profile to a depth of at least 120 cm.

2. Determine the soil texture throughout the profile to a depth of 120 cm. Use the Texture Group Table to evaluate and assign an appropriate Texture Group for the upper 0-70 cm zone of the profile. When the textures in the 0-70 cm zone are highly variable it may be appropriate to place more emphasis on the deeper texture conditions (i.e., 70-120 cm).

3. Use a measuring tape to determine the depth to distinct mottles. Ensure that the mottled zone is continuous to the bottom of the profile (i.e., a water table influence). In most cases, a discontinuous mottled zone indicates there is an obstruction to water percolation down through the profile. These obstructions are caused by so-called “hesitation” layers or zones characterized by significant changes in particle size. In extreme cases, this can cause a perched water table. If hesitation layers or perched water tables are observed, refer to the “100-150 cm” column of Depth to Distinct Mottles in the Tree Species Suitability Tables.

4. Use 10 % solution of HCI and a measuring tape to determine depth to carbonates. The calcium carbonate form of “free lime” will effervesce readily if present. If the magnesium carbonate form of free lime predominates, effervescence will be audible but not visible.

5. Resistance to excavation by shovel or auger occurs may indicate the presence of root-restricting conditions, formed by geological and/or soil development processes or by compaction due to past land use activities.

Use the data collected above to allocate the site to an appropriate position in the matrix tables. Compare the Productivity Rating and Site Index values of desirable species to be planted or managed. Match the most appropriate species to the site.

Remember that soil and site features are important but only two of many factors that influence tree species prescriptions.

LIMITATIONS OF THE SPECIES SUITABILITY TABLES

Since the on-site tables were developed from data from a limited number of samples, users should exercise caution when using them to predict potential tree species performance. Also, users should be aware that no sampling of stands from eastern Ontario was done (i.e., sampling was restricted to the former (pre 1996) southwestern and central regions of OMNR).

American Beech 6E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Poor***	Mod	Poor	Very Poor	Very Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor***	**Good***	Mod*	Poor	Poor		
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Poor	Mod	Mod	Mod	Poor		
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Mod**	Very Good	Good	**Good***		
Silty	Silt Silt loam	**Poor***	Mod	Very Good	Good	Mod		
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	Poor	Mod	Good	Good	**Good***		
Clayey	Silty clay Sandy clay Clay Heavy clay		Mod	Mod	Good			
Shallow	Any texture where depth to bedrock < 50 cm			**Very Poor***	Very Poor	Very Poor		

Productivity Rating
Very Good = SI(50) ≥22.0
Good = SI(50) 20.0-21.9
Mod = SI(50) 18.0-19.9
Poor = SI(50) 16.0-17.9
Very Poor = SI(50) ≤ 15.9

* Insufficient data for proper Productivity Rating Assessment
“c” Indicates Site when free carbonates are within 50 cm
“r” Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

American Beech 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	Poor	**Mod***	**Good***	**Good***	**Very Poor***		
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Poor	Mod	Mod	Good	Poor		
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	Mod	**Poor***	**Good**	**Mod***	**Poor***	Very Poor
Silty	Silt Silt loam	Poor	Mod	Good	**Very Good***	**Good***	**Good**	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor**	Mod	Mod	Good	**Mod***	Poor	**Very Poor***
Clayey	Silty clay Sandy clay Clay Heavy clay		**Poor***	Mod	Mod	**Poor***		
Shallow	Any texture where depth to bedrock < 50 cm			Very Poor	Very Poor	Very Poor		

Productivity Rating
Very Good = SI(50) ≥25.0
Good = SI(50) 23.0-24.9
Mod = SI(50) 21.0-22.9
Poor = SI(50) 19.0-20.9
Very Poor = SI(50) ≤ 18.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Basswood 6E

Texture Group	Textures	Depth to Distinct Mottles						
		>150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Poor	**Mod***	Poor	Very Poor	Very Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor* cr**	**Good***	**Mod***	Poor	Poor	Very Poor	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Poor***	Good	Mod	**Poor***	Poor	Very Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Poor**	**Very Good**	Very Good	**Poor***	**Mod**	**Very Poor***	
Silty	Silt Silt loam	**Poor***	Mod	Good	Mod	Mod	**Mod***	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	Poor	**Mod**	**Mod**	**Poor***	**Poor***	**Very Poor***	
Clayey	Silty clay Sandy clay Clay Heavy clay		Poor	**Poor***	Poor	Very Poor	Very Poor	
Shallow	Any texture where depth to bedrock < 50 cm			**Mod***	Poor	**Poor***	Very Poor	

<u>Productivity Rating</u>
Very Good = SI(50) ≥23.0
Good = SI(50) 21.0-22.9
Mod = SI(50) 19.0-20.9
Poor = SI(50) 17.0-18.9
Very Poor = SI(50) ≤ 16.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Basswood 7E

Texture Group	Textures	Depth to Distinct Mottles						
		>150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size			Poor	Poor	Poor	**Very Poor***	
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand		Poor	Mod	Mod	Mod	**Mod***	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm		**Mod***	Mod	Mod	Poor	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Very Good**	Good	**Mod***	**Mod**	**Poor***	
Silty	Silt Silt loam	Mod	Very Good	**Very Good***	Good	**Mod***	**Mod***	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Mod***	Good	Good	**Mod***	**Mod**	**Mod**	
Clayey	Silty clay Sandy clay Clay Heavy clay			Mod	Mod	Mod	**Mod***	
Shallow	Any texture where depth to bedrock < 50 cm			Poor	Poor	**Very Poor***	Very Poor	

Productivity Rating
Very Good = SI(50) ≥27.0
Good = SI(50) 25.0-26.9
Mod = SI(50) 23.0-24.9
Poor = SI(50) 21.0-22.9
Very Poor = SI(50) ≤ 20.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Black Cherry 6E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Poor**	Mod	Mod	Mod			
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Mod	**Good**	Mod	Mod	Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor***	Mod	**Good***	**Very Good**	**Mod**	Poor	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Poor**	**Good***	Good	Good	Mod	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Very Good**	Very Good	**Mod***	**Good***	**Mod***	
Silty	Silt Silt loam	**Mod***	Very Good	**Very Good***	Mod	**Poor***	Very Poor	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Good**	**Good***	**Poor***	**Mod***	**Poor***		
Clayey	Silty clay Sandy clay Clay Heavy clay							
Shallow	Any texture where depth to bedrock < 50 cm			**Poor***	**Mod**	Very Poor		

Productivity Rating

Very Good = SI(50) ≥24.0
Good = SI(50) 22.0-23.9
Mod = SI(50) 20.0-21.9
Poor = SI(50) 18.0-19.9
Very Poor = SI(50) ≤ 17.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Black Cherry 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	Poor	Mod	**Very Good***	**Good***	**Mod**	**Mod***	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Poor	Good	Good	Good	Mod	Mod	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Good***	**Very Good***	**Good**	**Good**	**Mod***	
Silty	Silt Silt loam	**Good***	Very Good	**Good***	**Mod***	**Poor***	Poor	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Very Poor***	Mod	Mod	**Mod**	**Poor***	**Very Poor***	
Clayey	Silty clay Sandy clay Clay Heavy clay				Mod	**Poor***	**Poor**	
Shallow	Any texture where depth to bedrock < 50 cm			**Mod***	Poor	**Poor***	Very Poor	

Productivity Rating

Very Good = SI(50) ≥27.0
Good = SI(50) 25.0-26.9
Mod = SI(50) 23.0-24.9
Poor = SI(50) 21.0-22.9
Very Poor = SI(50) ≤ 20.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Black Walnut 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand							
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm							
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Poor***	**Very Good***	Very Good	Good	**Good***	**Poor***	Very Poor
Silty	Silt Silt loam	Mod	Good	Very Good	Very Good	**Very Good***	Good	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor***	Good	Very Good	**Good***	**Mod***	**Poor***	**Very Poor***
Clayey	Silty clay Sandy clay Clay Heavy clay		**Very Good***	Good	Good	**Good***	**Mod**	**Poor***
Shallow	Any texture where depth to bedrock < 50 cm							

<u>Productivity Rating</u>
Very Good = SI(50) ≥27.0
Good = SI(50) 25.0-26.9
Mod = SI(50) 23.0-24.9
Poor = SI(50) 21.0-22.9
Very Poor = SI(50) ≤ 20.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Bitternut Hickory 7E

Texture Group	Textures	Depth to Distinct Mottles						
		>150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand			Mod	Mod	**Poor***	Very Poor	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Poor***	Mod	Good	Good	Mod	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Very Good***	**Good***	**Good**	**Mod**	**Poor***	Very Poor
Silty	Silt Silt loam	Mod	Very Good	**Good***	Good	**Good**	Mod	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Mod***	**Mod***	**Good***	**Very Good***	Mod	Poor	
Clayey	Silty clay Sandy clay Clay Heavy clay		**Poor***	Good	Mod	**Mod**	**Poor***	Very Poor
Shallow	Any texture where depth to bedrock < 50 cm			Poor	Mod	**Very Good***	**Mod**	**Very Poor**

Productivity Rating

Very Good = SI(50) ≥27.0
Good = SI(50) 25.0-26.9
Mod = SI(50) 23.0-24.9
Poor = SI(50) 21.0-22.9
Very Poor = SI(50) ≤ 20.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Maple 6E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Mod	Good	Mod	Poor			
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod***	Very Good	**Good**	**Mod***	**Poor***	**Poor***	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Mod	Good	Good	Mod	Poor	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	Mod	Very Good	Good	Mod	**Mod***	**Poor***	
Silty	Silt Silt loam	Good	Very Good	Good	Mod	Poor	Very Poor	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Very Good***	Very Good	Good	Mod	**Very Poor***	Very Poor	
Clayey	Silty clay Sandy clay Clay Heavy clay							
Shallow	Any texture where depth to bedrock < 50 cm			**Poor***	Poor	Mod		

Productivity Rating
Very Good = SI(50) ≥24.0
Good = SI(50) 22.0-23.9
Mod = SI(50) 20.0-21.9
Poor = SI(50) 18.0-19.9
Very Poor = SI(50) ≤ 17.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Maple 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Poor***	Mod	Mod	Mod	Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	Poor	Good	**Mod***	**Good***	**Poor***		
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Very Poor***	Mod	Good	Good	Mod		
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod***	**Mod***	Good	**Good**	**Good***	**Good**	
Silty	Silt Silt loam	Mod	Very Good	Very Good	Good	Good	Mod	Mod
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	Mod	Good	Very Good	Mod	Good	**Mod***	**Mod***
Clayey	Silty clay Sandy clay Clay Heavy clay		**Good***	Good	Mod	Mod	**Mod**	**Poor***
Shallow	Any texture where depth to bedrock < 50 cm							

Productivity Rating

Very Good = SI(50) ≥26.0
Good = SI(50) 24.0-25.9
Mod = SI(50) 22.0-23.9
Poor = SI(50) 20.0-21.9
Very Poor = SI(50) ≤ 19.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Oak 6E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Poor***	**Good***	Good	Mod	Poor		
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Poor**	Good	Good	Good	Mod	Poor	
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod**	**Good***	Very Good	**Very Good**	**Mod**	Poor	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Mod	Good	Very Good	**Good***	Mod	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Very Good***	Very Good	**Mod***	**Mod***	**Poor***	Very Poor
Silty	Silt Silt loam	Mod	Very Good	Very Good	Good	Mod	Poor	Very Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	Mod	Good	**Mod***	Mod	Poor	Very Poor	
Clayey	Silty clay Sandy clay Clay Heavy clay							
Shallow	Any texture where depth to bedrock < 50 cm			Very Poor	Poor			

<u>**Productivity Rating**</u>
Very Good = SI(50) ≥24.0
Good = SI(50) 22.0-23.9
Mod = SI(50) 20.0-21.9
Poor = SI(50) 18.0-19.9
Very Poor = SI(50) ≤ 17.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Oak 7E

Texture Group	Textures	Depth to Distinct Mottles: >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	Very Poor	Poor	Mod	Mod			
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Poor	Mod	Good	Good	Mod	Mod	
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	Mod	**Good***	**Very Good***	**Very Good**	**Good***	**Good**	Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Good***	Good	Good	Very Good	Good	Mod	Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Good**	Good	**Mod***	**Very Good**	**Good**	**Mod**	Poor
Silty	Silt Silt loam	**Good**	Very Good	Good	Mod	**Good***	**Very Good***	**Poor**
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Mod***	Mod	**Mod***	**Good***	**Good**	**Good**	**Good**
Clayey	Silty clay Sandy clay Clay Heavy clay		**Mod***	Mod	**Mod***	**Mod**	**Good**	**Mod**
Shallow	Any texture where depth to bedrock < 50 cm			**Good***	Good	**Poor***	Very Poor	Very Poor

Productivity Rating

Very Good = SI(50) ≥26.0
Good = SI(50) 24.0-25.9
Mod = SI(50) 22.0-23.9
Poor = SI(50) 20.0-21.9
Very Poor = SI(50) ≤ 19.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Pine Plantations 6E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size	Very Poor	**Mod**	Poor	Very Poor	Very Poor	Very Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Very Poor***	**Mod***	**Mod***	Poor	Mod	Very Poor	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod**	**Good**	**Very Good**	**Very Good / Mod r**	**Good**	**Mod**	**Poor**
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Mod**	Mod	Good	Mod	Poor	Poor	Very Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Very Good / Very Poor r**	Very Good / Very Poor c	**Good / Very Poor r**	**Very Good / Very Poor c**	**Mod**	**Mod***	**Poor**
Silty	Silt Silt loam	**Good**	Mod / Very Poor r	**Very Good**	**Mod / Very Poor r**	**Good/ Poor r**	**Poor**	Very Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Very Good***	Mod	Mod	**Mod***	**Poor***	**Very Poor***	Very Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Very Poor	Mod	Poor	Very Poor	Very Poor	Very Poor
Shallow	Any texture where depth to bedrock < 50 cm			**Good**	Mod	Very Poor	Very Poor	Very Poor

Productivity Rating
Very Good = SI(50) ≥23.0
Good = SI(50) 21.0-22.9
Mod = SI(50) 19.0-20.9
Poor = SI(50) 17.0-18.9
Very Poor = SI(50) ≤ 17.0

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Red Pine Plantation 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Very Poor***	**Mod***	Poor	Very Poor	Very Poor	Very Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Very Poor	Mod	Mod	Mod	Mod	Poor	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor**	**Good**	**Very Good**	**Good**	**Good**	**Mod**	Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Very Poor**	Mod	**Very Good***	**Good**	Mod	Poor	Very Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Good / Poor c**	**Good***	**Good**	**Good**	**Mod**	**Mod**	Very Poor
Silty	Silt Silt loam	**Good / Poor r**	Good / Poor	**Good* / Poor* r**	**Very Good**	**Good***	**Mod***	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Good**	Good	**Mod***	Mod	Mod	Mod	Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Mod	Mod	Poor	Very Poor	**Very Poor**	Very Poor
Shallow	Any texture where depth to bedrock < 50 cm			**Poor***	**Poor***	**Mod**	Very Poor	Very Poor

Productivity Rating
Very Good = SI(50) ≥25.0
Good = SI(50) 23.0-24.9
Mod = SI(50) 21.0-22.9
Poor = SI(50) 19.0-20.9
Very Poor = SI(50) ≤ 18.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Silver Maple 6E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand					Mod	**Mod***	Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm					Poor	Mod	Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam					**Mod***	**Mod**	**Poor***
Silty	Silt Silt loam					Mod	Very Good	Good
Fine Loamy	Clay loam Silty clay loam Sandy clay loam						**Mod**	Mod
Clayey	Silty clay Sandy clay Clay Heavy clay						**Very Good**	**Mod**
Shallow	Any texture where depth to bedrock < 50 cm							

Productivity Rating
Very Good = SI(50) $\geq$24.0
Good = SI(50) 22.0-23.9
Mod = SI(50) 20.0-21.9
Poor = SI(50) 18.0-19.9
Very Poor = SI(50) $\leq$ 17.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Silver Maple 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand				**Mod***	**Good**	**Mod**	Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm				Poor	Good	Good	Mod
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam				**Mod***	**Very Good**	**Very Good**	Mod
Silty	Silt Silt loam					Good	**Very Good***	Mod
Fine Loamy	Clay loam Silty clay loam Sandy clay loam					**Mod**	**Good**	**Very Poor***
Clayey	Silty clay Sandy clay Clay Heavy clay					**Poor***	**Good**	**Mod**
Shallow	Any texture where depth to bedrock < 50 cm							

Productivity Rating
Very Good = SI(50) ≥28.0
Good = SI(50) 26.0-27.9
Mod = SI(50) 24.0-25.9
Poor = SI(50) 22.0-23.9
Very Poor = SI(50) ≤ 21.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Sugar Maple 6E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Poor**	Mod	Mod	Mod	**Poor**		
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Mod**	Good	Poor	Poor	Very Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod**	**Very Good**	**Mod**	**Poor***	**Poor***		
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Mod**	**Mod***	Mod	**Good**	Poor	Very Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Very Good**	**Good**	**Good**	**Mod**	Very Poor	
Silty	Silt Silt loam	**Mod**	**Very Good**	**Good**	**Good**	**Mod**	Very Poor	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Good**	**Very Good**	**Good***	**Mod**	**Mod**	Very Poor	
Clayey	Silty clay Sandy clay Clay Heavy clay		**Poor***	**Good**	Poor	Very Poor		
Shallow	Any texture where depth to bedrock < 50 cm			**Mod**	**Mod**	**Very Poor**		

Productivity Rating
Very Good = SI(50) ≥22.0
Good = SI(50) 20.0-21.9
Mod = SI(50) 18.0-19.9
Poor = SI(50) 16.0-17.9
Very Poor = SI(50) ≤ 15.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Sugar Maple 7E

		Depth to Distinct Mottles						
Texture Group	Textures	>150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	Mod*	Good*	Good	Mod	Very Poor		
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Poor	Good	Mod	Good	Very Poor	Very Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	Mod	Good	Very Good	Mod	Mod	Mod	
Silty	Silt Silt loam	Good	Very Good	Very Good	Good*	Good*	Mod*	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	Mod	Good	Mod*	Good*	Good	Mod	Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Good*	Very Good*	Good*	Good*	Mod	Poor*
Shallow	Any texture where depth to bedrock < 50 cm			Mod*	Very Good*	Good*	Poor*	

Productivity Rating
Very Good = SI(50) ≥26.0
Good = SI(50) 24.0-25.9
Mod = SI(50) 22.0-23.9
Poor = SI(50) 20.0-21.9
Very Poor = SI(50) ≤ 19.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Ash 6E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size							
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand		Mod	Good	Mod	**Mod**	**Poor**	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Mod**	Good	Good	**Good***	Mod	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Good**	**Very Good**	**Good***	**Mod**	**Mod**	Poor	
Silty	Silt Silt loam	**Good***	Very Good	Very Good	Mod	Poor*	Very Poor	
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Mod**	**Very Good***	**Mod***	**Mod***	Poor	**Very Poor ***	
Clayey	Silty clay Sandy clay Clay Heavy clay		**Poor***	Mod	Mod	Poor	Very Poor	
Shallow	Any texture where depth to bedrock < 50 cm			**Very Poor**	**Mod***	**Poor***		

<u>Productivity Rating</u>
Very Good = SI(50) ≥25.0
Good = SI(50) 23.0-24.9
Mod = SI(50) 21.0-22.9
Poor = SI(50) 19.0-20.9
Very Poor = SI(50) ≤ 18.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E. P. and R. K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Ash 7E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Poor***	Mod	Mod	Good	Poor		
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor***	**Mod***	Good	**Very Good***	**Mod***	Very Poor	
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Poor***	Mod	Good	Good	Mod	Poor	
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Good**	**Very Good**	**Good***	**Mod**	**Mod**	Poor
Silty	Silt Silt loam	**Mod***	Very Good	**Good***	**Mod***	**Mod**	Poor	**Very Poor***
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor***	**Mod***	Good	**Very Good**	**Very Good**	**Mod**	**Good ***
Clayey	Silty clay Sandy clay Clay Heavy clay		**Mod***	Good	Good	**Mod**	**Mod**	**Good**
Shallow	Any texture where depth to bedrock < 50 cm			**Poor***	Mod	Good	Mod	**Mod***

<u>Productivity Rating</u>
Very Good = SI(50) ≥28.0
Good = SI(50) 26.0-27.9
Mod = SI(50) 24.0-25.9
Poor = SI(50) 22.0-23.9
Very Poor = SI(50) ≤ 21.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Pine Plantations 6E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Poor***	**Good***	Good	Mod	Mod	Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Poor**	Mod	**Mod**	Good	Mod	Poor	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor**	**Good**	**Very Good**	**Good**	**Mod**	**Poor***	**Very Poor**
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Mod / Very Poor c***	**Good**	Very Good	Good	**Poor***	Poor	Very Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod / Very Poor c**	**Very Good**	**Good**	**Very Good**	**Good**	**Mod**	**Poor**
Silty	Silt Silt loam	**Good**	Very Good	Very Good	Good	**Mod**	Mod	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Very Poor**	Good	Good	**Poor***	**Good**	Mod	Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Mod	Mod	Poor	Poor	**Poor**	Very Poor
Shallow	Any texture where depth to bedrock < 50 cm			**Poor**	Mod	**Very Good**	Mod	Very Poor

Productivity Rating

Very Good = SI(50) ≥26.0
Good = SI(50) 24.0-25.9
Mod = SI(50) 22.0-23.9
Poor = SI(50) 20.0-21.9
Very Poor = SI(50) ≤ 19.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Pine Plantations 7E

Texture Group	Textures	Depth to Distinct Mottles						
		>150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Very Poor***	Poor	Mod	Mod	Poor	Very Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Poor	Poor	Good	Mod	Mod	Poor	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Poor**	**Good**	**Very Good**	**Mod**	**Mod**	**Poor**	Very Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Very Poor c***	Mod / Very Poor c	Good	Mod	Mod	Poor	Very Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod** / Very Poor c	**Good***	**Good***	**Mod**	**Mod**	**Mod**	Poor
Silty	Silt Silt loam	**Mod***	Very Good	**Good***	**Mod**	**Mod**	**Mod**	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor**	Good	Good	**Mod***	**Mod**	**Poor***	Very Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Mod	Good	Mod	Mod	**Mod**	Poor
Shallow	Any texture where depth to bedrock < 50 cm			**Poor***	**Mod**	**Good***	**Poor**	Very Poor

Productivity Rating
Very Good = SI(50) ≥28.0
Good = SI(50) 26.0-27.9
Mod = SI(50) 24.0-25.9
Poor = SI(50) 22.0-23.9
Very Poor = SI(50) ≤ 21.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Spruce Plantations 6E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	**Very Poor**	Poor	Mod	Mod	Poor	Very Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	**Good***	Mod	Good	Mod	Poor	**Very Poor***	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod**	**Mod**	**Good**	**Very Good**	**Mod**	Poor	Very Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	Mod	**Good***	Good	Mod	**Very Poor**	Very Poor	Very Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Good**	Very Good	**Mod**	**Mod**	**Mod**	**Very Poor**
Silty	Silt Silt loam	**Very Good**	**Good***	Very Good	Mod	**Mod***	**Poor**	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor**	Mod	Mod	**Very Poor**	**Poor**	**Mod**	**Poor**
Clayey	Silty clay Sandy clay Clay Heavy clay		**Very Poor cr**	Mod	Very Poor	Very Poor	**Very Poor**	Very Poor
Shallow	Any texture where depth to bedrock < 50 cm			Poor	Mod	Poor	Very Poor	Very Poor

Productivity Rating

Very Good = SI(50) ≥26.0
Good = SI(50) 24.0-25.9
Mod = SI(50) 22.0-23.9
Poor = SI(50) 20.0-21.9
Very Poor = SI(50) ≤ 19.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Spruce Plantation 7E

Texture Group	Textures	Depth to Distinct Mottles >150 cm	100-150 cm	80-100 cm	50-80 cm	30-50 cm	15-30 cm	<15 cm
Very Gravelly	All textures with > 50% of particles > 2 mm in size	Very Poor	Mod	Mod	Poor	Poor	Very Poor	Very Poor
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size	Poor	Mod	Good	Mod	Mod	Poor	Very Poor
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand	**Mod**	**Good**	**Very Good**	**Mod**	**Good**	**Mod**	Poor
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm	**Good**	Good	Very Good	Mod	Mod	Mod	Poor
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam	**Mod**	**Mod**	**Very Good***	**Poor**	**Mod**	**Mod**	Poor
Silty	Silt Silt loam	**Mod***	Good	Very Good	**Mod**	**Poor**	**Poor**	Poor
Fine Loamy	Clay loam Silty clay loam Sandy clay loam	**Poor***	Good	Very Good	Good	**Mod**	**Poor***	Poor
Clayey	Silty clay Sandy clay Clay Heavy clay		Poor	Mod	Good	**Good***	Mod	Poor
Shallow	Any texture where depth to bedrock < 50 cm			Poor	Poor	Mod	**Mod***	Very Poor

<u>**Productivity Rating**</u>
Very Good = SI(50) ≥27.0
Good = SI(50) 25.0-26.9
Mod = SI(50) 23.0-24.9
Poor = SI(50) 21.0-22.9
Very Poor = SI(50) ≤ 20.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

White Oak 7E

		Depth to Distinct Mottles						
Texture Group	**Textures**	**>150 cm**	**100-150 cm**	**80-100 cm**	**50-80 cm**	**30-50 cm**	**15-30 cm**	**<15 cm**
Very Gravelly	All textures with > 50% of particles > 2 mm in size							
Gravelly Sandy	All sandy textures with 20-50% of particles > 2 mm in size			Very Poor	Poor	Poor	**Poor***	Mod
Sandy	Very coarse sand Coarse sand Medium sand Fine sand Loamy very coarse sand Loamy coarse sand Loamy medium sand Loamy fine sand			Poor	Poor	Mod	**Good**	**Very Good***
Gravelly Loamy	All coarse loamy textures with 2-50% of particles > 2 mm		Very Poor	Poor	Poor	Mod	Good	Good
Coarse Loamy	Very fine sand Loamy very fine sand Sandy loams Loam		Poor	Mod	**Mod***	Good	**Very Good***	Good
Silty	Silt Silt loam		Poor	God	**Mod***	Good	**Very Good***	Mod
Fine Loamy	Clay loam Silty clay loam Sandy clay loam			Mod	**Good**	**Very Good**	**Mod***	Poor
Clayey	Silty clay Sandy clay Clay Heavy clay			Very Poor	**Mod***	**Good**	**Good**	**Poor***
Shallow	Any texture where depth to bedrock < 50 cm				Very Poor	Poor	**Good**	Very Poor

Productivity Rating

Very Good = SI(50) ≥23.0
Good = SI(50) 21.0-22.9
Mod = SI(50) 19.0-20.9
Poor = SI(50) 17.0-18.9
Very Poor = SI(50) ≤ 16.9

* Insufficient data for proper Productivity Rating Assessment
"c" Indicates Site when free carbonates are within 50 cm
"r" Indicates Site when a root restricting layer occurs
Greyed Ratings = Subjective extrapolation of Productivity Rating

Source: Taylor, E.P. and R.K. Jones. 1986. Soil interpretation and training in forestry 1981-1985 in central and southwestern regions site region 6E and 7E. Ontario Institute of Pedology.

Appendix E

Stocking Guides for Some Southern Ontario Tree Species

American Beech
Basswood
Black Cherry
Eastern Hemlock
Red Maple
Red Pine
Red Oak
Sugar Maple
White Ash
White Birch
White Pine
Yellow Birch

adapted from OMNR 1998*a* and *b*

HOW TO USE A STOCKING GUIDE

Stocking guides are decision support tools used in **even-aged** management to show the relationship between the number of trees and basal area, stocking per cent, and quadratic mean diameter for trees in the stand. These guides provide an assessment of the stand's use of available growing space and suggest when growing space is limited and thinnings should be considered to meet management objectives (usually this means to maintain optimum growth).

When using a stocking guide make sure that you are using one that is most appropriate for your stand condition. Species and site factors influence the development of local stocking guides. **Appendix E** provides examples of stocking guides that are appropriate for most species in Ontario. Where stocking guides have not been created for an individual species or where local site conditions are different from where the stocking guide was created, it is recommended that those developed by Leak *et al.* (1987) or Tubbs (1977*b*) be used. Stocking guides presented in this section are for single species and should only be applied in stands dominated (> 70 %) by the given species.

Stocking guides are simply graphs with the number of trees per area on the X-axis and basal area per area on the Y-axis (see **Figure 5.2.2**). On the graph there are also two series of lines that show the quadratic mean diameter for trees in the stand and the level of stocking. Stocking levels are usually presented as "A", "B", and "C" lines. The "A" line represents the normal condition of maximum stocking for undisturbed stands of average structure. At this line the stand is fully utilizing or occupying the site. The "B" line is the lower limit of stocking needed for full occupancy of the site. This is where crowns are fully developed and are just touching each other. In general for tolerant hardwoods, the "B" is approximately 58 % of the "A" line level. Stands at the "C"-level are currently understocked but are expected to reach the "B" level within 10 years (Gingrich 1967).

The stocking guides developed by Gingrich (1967) for upland hardwoods in the central United States have been adapted to meet local stand and site conditions, stocking standards, and management objectives. Tubbs (1977*b*) developed a stocking guide for site conditions and management objectives in the Lakes States. Leak *et al.* (1987) produced a stocking guide for beech-red maple and beech-birch-maple stands in New England. Work is ongoing to validate these guides to Ontario conditions.

The number of trees and basal area per hectare is needed to use a stocking guide. Stands stocking level and quadratic mean diameter are determined by the intersection of stand density and basal area. From this location the crown cover can be determined.

When stocking is at the "A" level , the stand is fully stocked and growing space is fully utilized. If it is above the "A" level, growing space is over-utilized and there will be mortality and self-thinning. In this condition, individual tree and stand growth is low, and individual tree mortality offsets growth to keep stocking at the "A"-level. Growing space is also fully utilized between "A"- and "B"-level stocking. Stands grow, but growth on individual trees varies greatly. Below “B”-level stocking, growing space is not fully utilized and optimum use of the resources does not occur.

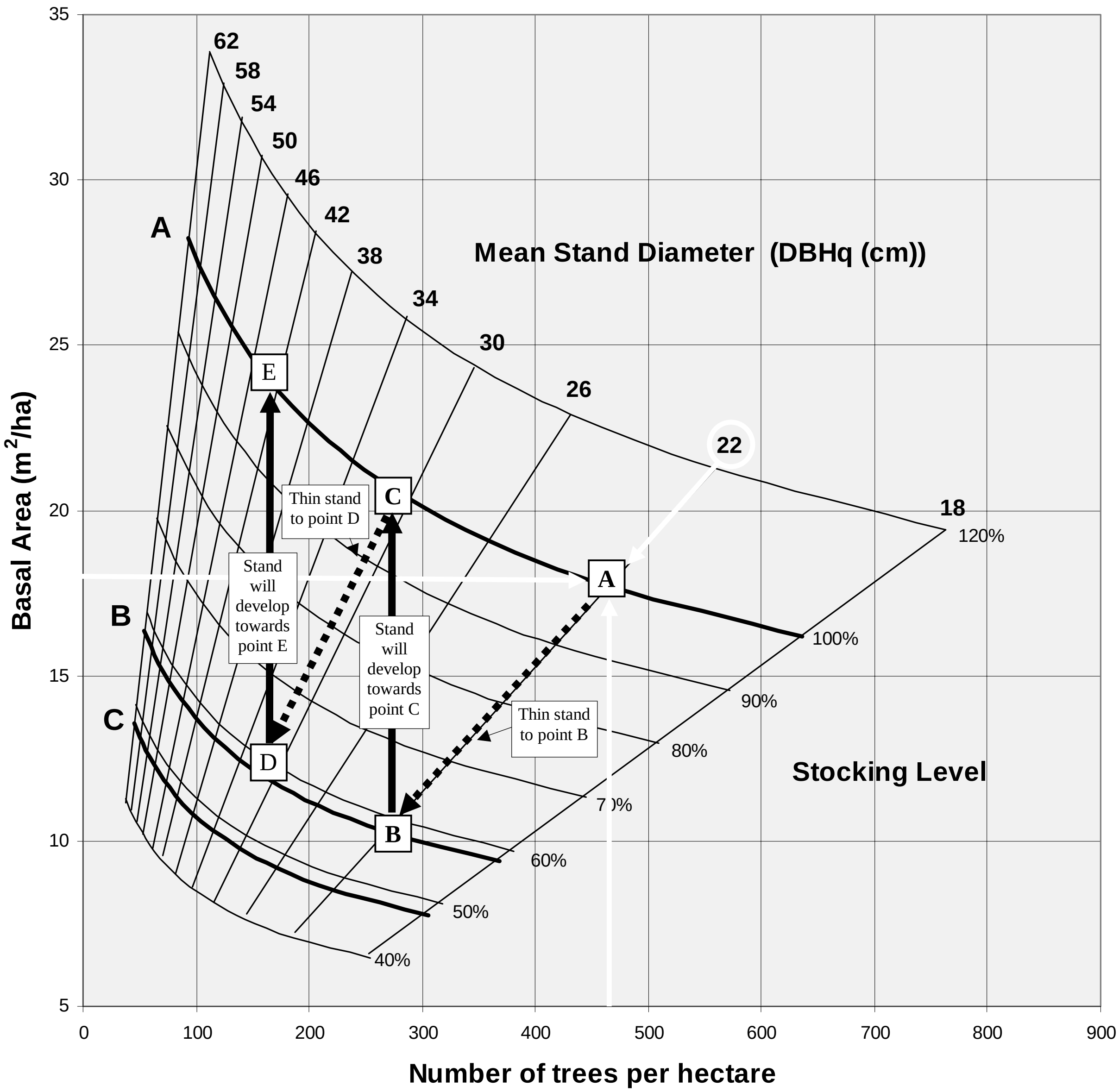
Thinning is recommended in stands that are at or above the “A”-level. Individual tree growth is highest when the stand is thinned to the “B”-level. In thinning the stand, the number of trees and basal area will be lowered, but the quadratic mean diameter of the stand should remain roughly the same or increase if thinning removes the smaller diameter trees. Changes in stand conditions can be projected by moving down the appropriate quadratic mean diameter line to the post harvest density level. Growth can be predicted by moving the stand parallel to the Y-axis (i.e. the number of trees remains the same, but as trees grow the basal area will increase). Thinning should be scheduled again when stands reach the “A”-level, if maximizing tree growth is a main objective.

Thinning stands between the “A”- and “B”-levels, to the “B”-level may increase individual tree growth but at the expense of overall stand growth. Thinning in this zone is done to meet non-timber management objectives.

Stands below the “B”-level should not be thinned.

In the example shown below the current stand condition is identified at point A. It is positioned at the 100 % stocking level (“A” - line). At this level a thinning is prescribed. The stand is thinned to position B (the “B” line). This lowers the basal area and the number of trees by maintaining the mean stand diameter (DBHq). Trees remaining in the stand at point B will grow to point C (100 % stocking level). This process is repeated again where trees are thinned from point C to point D. Trees remaining grow from point D to point E.

Figure E-1: Example application of a stocking guide.



Summary Table

Point	Basal Area (m2/ha)	Number of trees/ha	Dbhq (cm)
A	18	475	22
B	11	280	22
C	21	280	31
D	12	160	31
E	24	160	44

For thinning red pine and white pine stands, however, density management diagrams (DMD) provide a more precise estimate of when to thin even-aged stands. DMDs are provided for both red tario stands. Although DMDs are based on the same biological principles as stocking guides, they provide additional value to forest managers: when planning forest operations, managers can estimate time intervals between different stages of stand development. These time intervals can be inferred from stand top height values, as long as the Site Index (SI) of the stand is known.

HOW TO USE A DENSITY MANAGEMENT DIAGRAM

Density Management Diagrams (DMD) are constructed using four parameters: quadratic mean diameter, stand top height, density and mean tree volume. Three of these parameters can be calculated or assessed in the field. The fourth, mean tree volume, can be read directly from the diagram. While it is recommended that the remaining three parameters be used to place the subject stand on the diagram, only two are necessary. In addition, breast-height age should be estimated so that site index (SI) of the stand can be determined.

1. *Quadratic Mean Diameter (DBHq)*: This is the diameter (cm) of the tree of average mean basal area. For practical purposes average DBH can be used in preference to DBH_q, but using DBH_q is more precise.

2. *Stand Top Height (or Dominant Height)*: By definition, this is the average height (m) of the largest 100 stems (by diameter) per hectare. The average total height (m) of the dominant trees in the upper canopy of the stand can also be used as a rough estimate of stand top height.

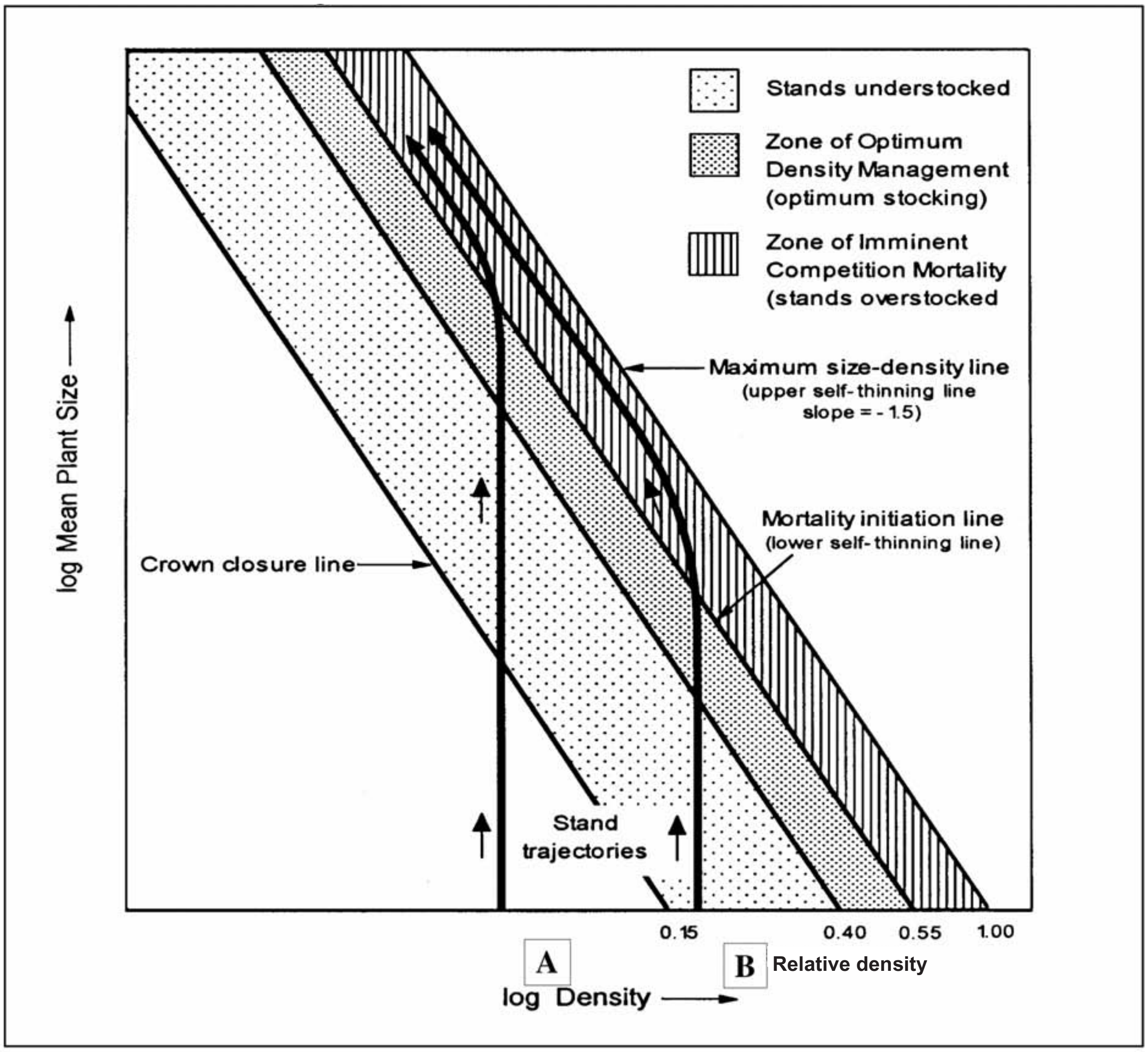
3. *Density*: The number of stems per hectare determined by counting the number of stems in several fixed area plots randomly located in the stand (as described in **Appendix C**).

4. *Breast Height Age*: If stand age is known then breast-height age can be estimated. For example, for red pine subtract 5 years for breast-height age and 6 years for white pine. If stand age is unknown, breast-height age can be quickly estimated by taking an increment core (at 1.3 m) from a dominant tree (select one that was used for the stand top height calculation) and then counting the growth rings.

The inclusion of stand quadratic mean diameter and top height isolines on the DMD permits additional stand development information to be derived, and they also provide a further check when locating stands on the DMD. By superimposing a stands' position on the diagram, silvicultural decisions can be made to ensure that a stand develops trees of a desired size. Future estimates of density, quadratic mean diameter (DBH_q), and basal area (BA), plus **approximations** of mean tree and total stand volume estimates can be derived from the DMD. Site index curves provide a temporal scale that permit resource managers to determine timing of successive thinning operations. Top height values for a stand positioned on the DMD can be interpreted into stand age when the subject stands SI is known.

Two stand development trajectories (for Stand A and B) are presented in **Figure E-2**. Stand A has a lower initial density than stand B. As average tree size increases during the early stages of stand growth, density remains unchanged, and the trajectories of stand development remain vertical. As growth continues, competition between individuals increases and the rate of growth

Figure E-2: Example of stand development trajectories for two stands on a density management diagram.

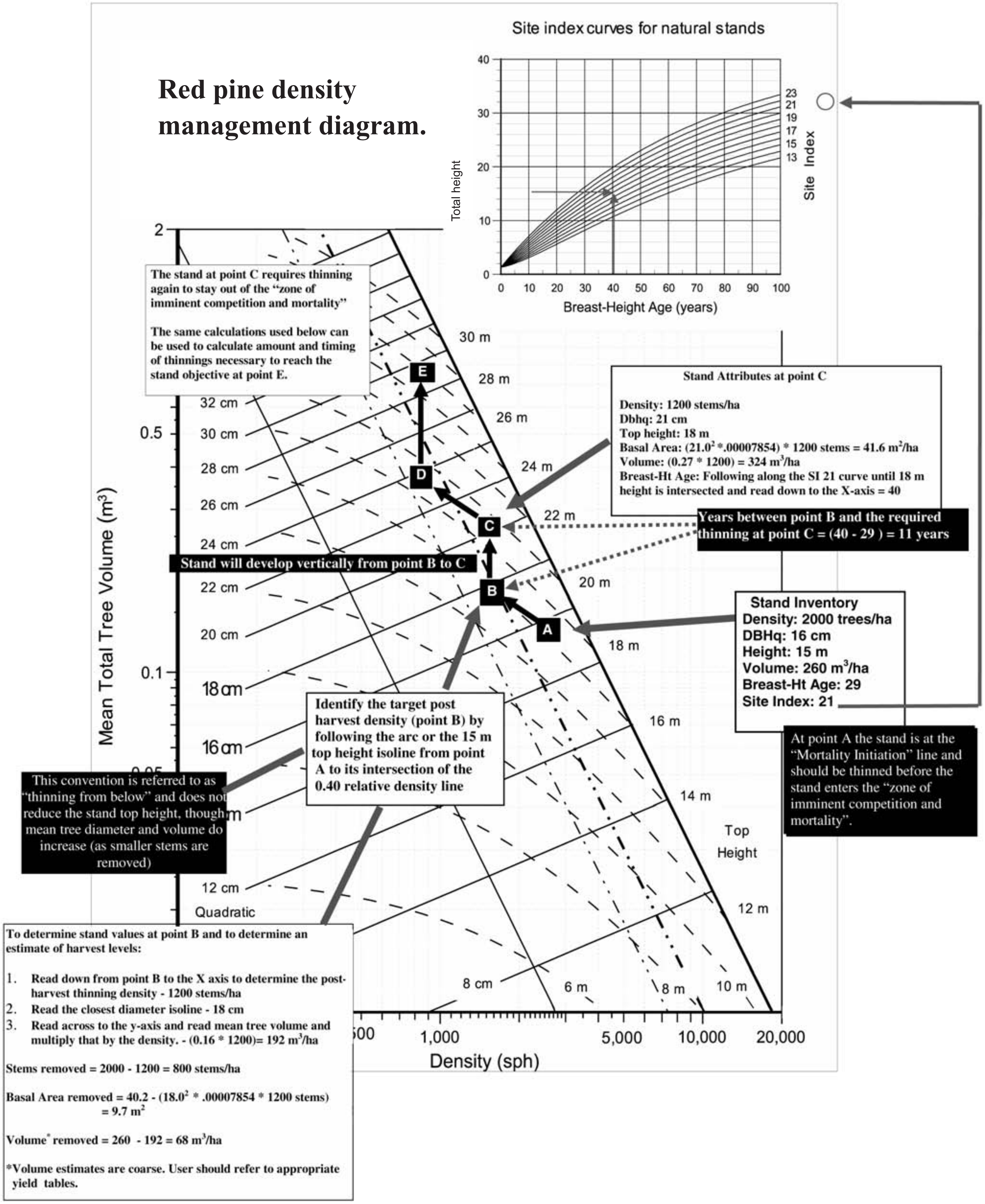


declines, then some trees will begin to die. Density-dependent mortality will occur earlier in stands where densities are initially higher (Stand B). Once the stands cross the *"mortality initiation"* line, this process accelerates. After stands enter the *"zone of imminent competition and mortality"* (ZICM) they remain there and enter a prolonged self-thinning phase. As the stand develops toward maturity there is a continual increase in mean tree size, and weaker individuals will continue to die. From the onset of the self-thinning phase the trajectory of stand development remains within the ZICM boundaries. If the stand enters the over-maturity stage and begins to break-up, then the trajectory may well drop below the lower ZICM boundary.

Figure E-3 illustrates an example of how to use a DMD. Only the even numbered DBHq and top height isolines are illustrated on the DMD for presentation purposes. Odd numbered isolines can be interpreted. Point A represents the intersection of three variables: 2000 trees/ha; 16 cm DBHq; and 15 m top height. The stand is situated at the *"mortality initiation"* line and should be thinned before the stand enters the ZICM and begins to lose volume to mortality. The objective in the example provided is to maximise stand volume growth. To do this, the stand should be thinned to the 0.40 relative density line. To identify this point, move following the arc of the top height isolines (15 m) to the intersection of the 0.40 relative density line. This is identified as point B. The calculation of thinning values is presented on the diagram. From point B the stand will develop vertically toward the *"mortality initiation"* line (point C). The number of years required by the stand to reach point C from point B can be calculated using the site index curves provided. The stand in this example has a SI of 21. At point B, the stand has a breast-height age of 29 years (add 5 years for red pine total age and 6 for white pine). This is based on a top height of 15 m and a SI of 21 (refer to SI curves in **Figure E-3**). At point C, the stand has a top height of 18 m and a breast-height age of 40 years (obtained from the SI curves). The projected number of years that are required for the stand to grow from point B to C is 11 (40-29) years.

At point C the stand will require another thinning. The same process that was used for calculating a thinning prescription is again applied. The only variation is in the estimation of point D. In this example, a decision was made to ensure that following this thinning the next harvest would occur when the stand had achieved a DBHq of 30 cm. To place point E on the DMD, simply identify the intersection of the 30 cm DBHq isoline and the *"mortality initiation"* line. This point is then labelled as point E. Now draw a line vertically downward until a line drawn along the arc of the 18 m top height isoline from point C is intersected. This point is labelled as point D. Calculations for point D and E are determined as described earlier. For further information and more detail refer to Smith and Woods (1997).

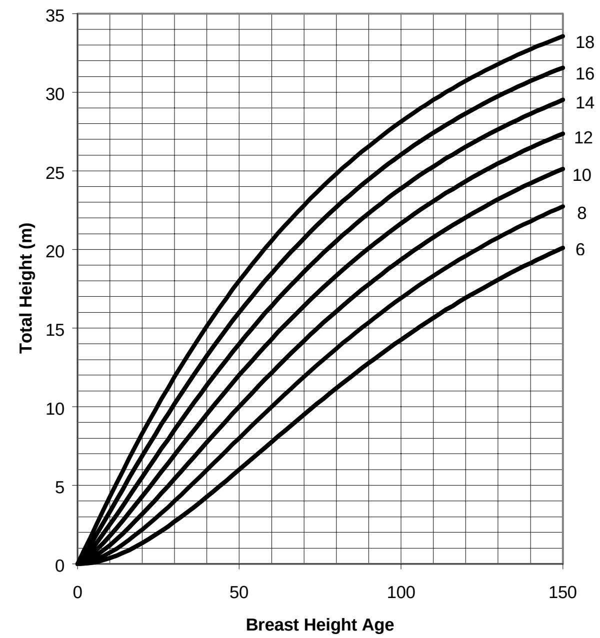
Figure E-3: How to use a density management diagram.



American Beech Growth & Yield Factsheet

Age	Site Index 6	8	10	12	14	16	18
5	0.1	0.2	0.4	0.7	1.1	1.6	2.1
10	0.4	0.7	1.2	1.8	2.5	3.3	4.3
15	0.8	1.4	2.1	3.0	4.0	5.1	6.3
20	1.3	2.2	3.2	4.3	5.5	6.9	8.3
25	2.0	3.1	4.3	5.6	7.0	8.6	10.1
30	2.7	4.0	5.4	6.9	8.5	10.2	11.9
35	3.5	5.0	6.6	8.2	10.0	11.7	13.6
40	4.3	6.0	7.7	9.5	11.4	13.2	15.1
45	5.1	7.0	8.9	10.8	12.7	14.7	16.6
50	6.0	8.0	10.0	12.0	14.0	16.0	18.0
55	6.9	9.0	11.1	13.2	15.2	17.3	19.3
60	7.8	10.0	12.2	14.3	16.4	18.5	20.6
65	8.6	11.0	13.2	15.4	17.5	19.6	21.7
70	9.5	11.9	14.2	16.4	18.6	20.7	22.8
75	10.3	12.8	15.1	17.4	19.6	21.7	23.8
80	11.2	13.7	16.1	18.3	20.5	22.7	24.8
85	12.0	14.5	16.9	19.2	21.4	23.6	25.7
90	12.8	15.4	17.8	20.1	22.3	24.5	26.6
95	13.5	16.2	18.6	20.9	23.1	25.3	27.4
100	14.3	16.9	19.3	21.7	23.9	26.0	28.1
105	15.0	17.6	20.1	22.4	24.6	26.7	28.8
110	15.6	18.3	20.8	23.1	25.3	27.4	29.5
115	16.3	19.0	21.4	23.7	25.9	28.1	30.1
120	16.9	19.6	22.0	24.3	26.5	28.7	30.7
125	17.5	20.2	22.6	24.9	27.1	29.2	31.3
130	18.1	20.8	23.2	25.5	27.6	29.7	31.8
135	18.6	21.3	23.7	26.0	28.2	30.2	32.3
140	19.1	21.8	24.2	26.5	28.6	30.7	32.7
145	19.6	22.3	24.7	26.9	29.1	31.2	33.2
150	20.1	22.7	25.1	27.4	29.5	31.6	33.6

American Beech Site Index Curves



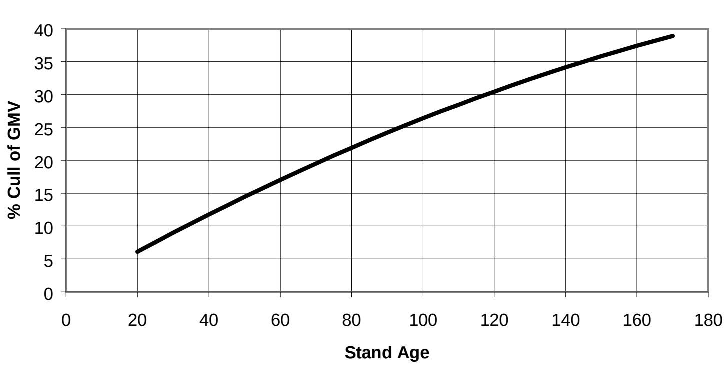
$$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	29.7300	0.3631	-0.0127	16.7616	-0.6804	0.99	0.49	0.4
SI	0.2376	1.1312	-0.0109	-1.8550	-0.1430	0.99	0.61	2.9

Data Source: Carmean 1978

Lake States Data. Number of trees used for equation derivation unknown.
Add 4 years to breast-height age to get total age.

Cull as a % of Gross Merchantable Volume



$$\textbf{Cull} = -0.0005*\text{Stand Age}^2 + 0.03136*\text{Stand Age}$$

Data Source: Basham, J.T. 1991. 393 trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%
5	1.56	90	24.17
10	3.09	95	25.28
15	4.59	100	26.36
20	6.07	105	27.42
25	7.53	110	28.45
30	8.96	115	29.45
35	10.36	120	30.43
40	11.74	125	31.39
45	13.10	130	32.32
50	14.43	135	33.22
55	15.74	140	34.10
60	17.02	145	34.96
65	18.27	150	35.79
70	19.50	155	36.60
75	20.71	160	37.38
80	21.89	165	38.13
85	23.04	170	38.86

American Beech Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0164	0.0241	0.0316	0.0388	0.0458	0.0525	0.0591	0.0654	0.0715	0.0774	0.0832	0.0887	0.0941	0.0994
12	0.0236	0.0347	0.0455	0.0559	0.0659	0.0757	0.0851	0.0941	0.1029	0.1115	0.1197	0.1278	0.1356	0.1431
14	0.0321	0.0473	0.0619	0.0761	0.0898	0.1030	0.1158	0.1281	0.1401	0.1517	0.1630	0.1739	0.1845	0.1948
16	0.0419	0.0617	0.0809	0.0994	0.1172	0.1345	0.1512	0.1674	0.1830	0.1982	0.2129	0.2271	0.2410	0.2544
18	0.0530	0.0781	0.1024	0.1258	0.1484	0.1702	0.1914	0.2118	0.2316	0.2508	0.2694	0.2875	0.3050	0.3220
20		0.0965	0.1264	0.1553	0.1832	0.2102	0.2363	0.2615	0.2860	0.3097	0.3326	0.3549	0.3765	0.3975
22		0.1167	0.1529	0.1879	0.2216	0.2543	0.2859	0.3164	0.3460	0.3747	0.4025	0.4294	0.4556	0.4810
24			0.1820	0.2236	0.2638	0.3026	0.3402	0.3766	0.4118	0.4459	0.4790	0.5111	0.5422	0.5724
26			0.2136	0.2624	0.3096	0.3552	0.3993	0.4420	0.4833	0.5233	0.5622	0.5998	0.6363	0.6718
28				0.3043	0.3590	0.4119	0.4631	0.5126	0.5605	0.6069	0.6520	0.6956	0.7380	0.7791
30				0.3493	0.4121	0.4728	0.5316	0.5884	0.6434	0.6968	0.7484	0.7986	0.8472	0.8944
32				0.3975	0.4689	0.5380	0.6048	0.6695	0.7321	0.7927	0.8516	0.9086	0.9639	1.0176
34				0.4487	0.5294	0.6073	0.6828	0.7558	0.8265	0.8949	0.9613	1.0257	1.0882	1.1488
36				0.5031	0.5935	0.6809	0.7655	0.8473	0.9265	1.0033	1.0777	1.1499	1.2200	1.2879
38				0.5605	0.6613	0.7587	0.8529	0.9440	1.0323	1.1179	1.2008	1.2812	1.3593	1.4350
40					0.7327	0.8406	0.9450	1.0460	1.1439	1.2387	1.3306	1.4197	1.5061	1.5900
42					0.8078	0.9268	1.0419	1.1533	1.2611	1.3656	1.4669	1.5652	1.6605	1.7530
44					0.8866	1.0171	1.1435	1.2657	1.3841	1.4988	1.6100	1.7178	1.8224	1.9239
46						1.1117	1.2498	1.3834	1.5128	1.6381	1.7597	1.8775	1.9918	2.1028
48							1.3608	1.5063	1.6472	1.7837	1.9160	2.0443	2.1688	2.2897
50							1.4766	1.6344	1.7873	1.9354	2.0790	2.2182	2.3533	2.4844
52							1.5971	1.7678	1.9332	2.0933	2.2486	2.3992	2.5453	2.6872
54								1.9064	2.0847	2.2575	2.4249	2.5873	2.7449	2.8978
56								2.0502	2.2420	2.4278	2.6079	2.7825	2.9520	3.1165
58									2.4050	2.6043	2.7975	2.9848	3.1666	3.3431
60									2.5737	2.7870	2.9937	3.1942	3.3888	3.5776
62									2.7482	2.9759	3.1967	3.4107	3.6184	3.8201
64									2.9283	3.1710	3.4062	3.6343	3.8557	4.0705
66									3.1142	3.3723	3.6224	3.8650	4.1004	4.3289
68									3.3058	3.5798	3.8453	4.1028	4.3527	4.5952
70										3.7934	4.0748	4.3477	4.6125	4.8695
72											4.3110	4.5997	4.8798	5.1517
74											4.5538	4.8588	5.1547	5.4419

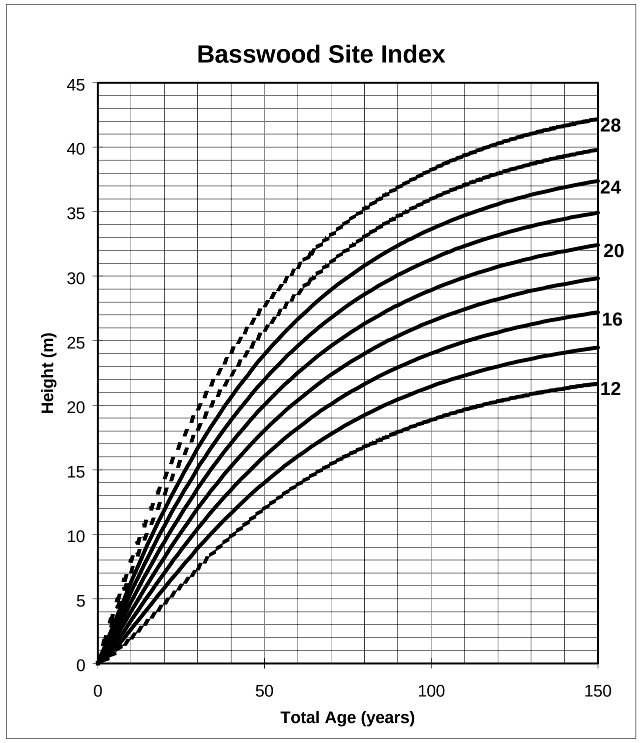
Honer's (1983) Total cubic metre volume equation

Volume (m^3) = 0.0043891*dbh^2 * (1-0.04365*0.145)^2 / (0.959+(0.3048*334.829/Height)) +/- 25.1 % Accuracy

Denotes range of data 388 Trees

Basswood Growth & Yield Factsheet

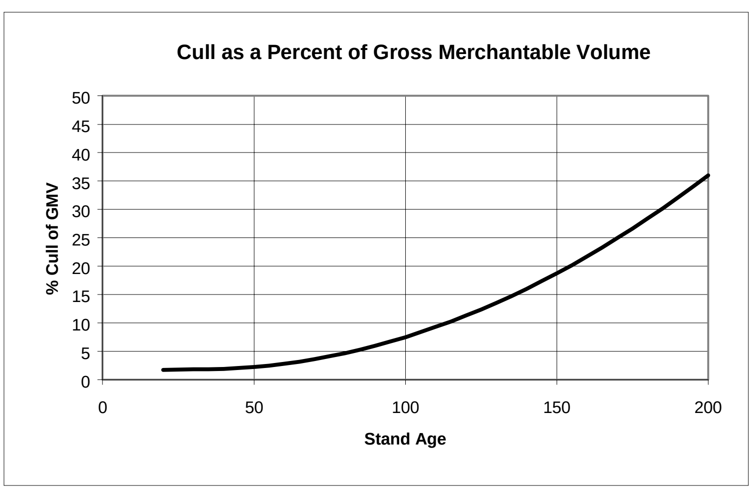
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.81	1.12	1.47	1.85	2.27	2.71	3.17	3.66	4.17
10	2.01	2.64	3.30	4.01	4.74	5.51	6.30	7.11	7.93
15	3.35	4.25	5.18	6.16	7.15	8.17	9.21	10.27	11.34
20	4.71	5.85	7.02	8.22	9.44	10.67	11.91	13.16	14.42
25	6.06	7.41	8.78	10.17	11.57	12.97	14.39	15.80	17.22
30	7.37	8.90	10.45	12.00	13.55	15.10	16.66	18.21	19.76
35	8.62	10.31	12.00	13.69	15.38	17.06	18.73	20.40	22.06
40	9.81	11.63	13.45	15.27	17.06	18.85	20.63	22.39	24.14
45	10.92	12.87	14.80	16.71	18.61	20.49	22.36	24.20	26.03
50	11.96	14.01	16.04	18.05	20.03	21.99	23.93	25.85	27.75
55	12.92	15.07	17.19	19.27	21.33	23.36	25.37	27.35	29.31
60	13.82	16.05	18.24	20.39	22.52	24.61	26.67	28.71	30.72
65	14.65	16.95	19.21	21.42	23.60	25.75	27.86	29.95	32.01
70	15.41	17.77	20.09	22.36	24.59	26.78	28.94	31.07	33.17
75	16.11	18.53	20.90	23.22	25.49	27.73	29.93	32.09	34.23
80	16.76	19.23	21.64	24.00	26.32	28.59	30.82	33.02	35.18
85	17.35	19.87	22.32	24.72	27.06	29.37	31.63	33.86	36.05
90	17.89	20.45	22.94	25.37	27.75	30.08	32.37	34.62	36.84
95	18.39	20.98	23.50	25.96	28.37	30.73	33.04	35.32	37.56
100	18.84	21.47	24.02	26.50	28.93	31.32	33.65	35.95	38.21
105	19.26	21.91	24.48	26.99	29.45	31.85	34.21	36.52	38.80
110	19.63	22.31	24.91	27.44	29.92	32.34	34.71	37.04	39.33
115	19.98	22.68	25.30	27.85	30.34	32.78	35.17	37.51	39.82
120	20.30	23.02	25.65	28.22	30.73	33.18	35.58	37.94	40.26
125	20.58	23.32	25.98	28.56	31.08	33.54	35.96	38.33	40.66
130	20.84	23.60	26.27	28.86	31.40	33.87	36.30	38.68	41.02
135	21.08	23.85	26.54	29.14	31.69	34.18	36.61	39.00	41.35
140	21.30	24.08	26.78	29.40	31.95	34.45	36.89	39.29	41.65
145	21.50	24.29	27.00	29.63	32.19	34.70	37.15	39.56	41.92
150	21.68	24.48	27.20	29.84	32.41	34.92	37.38	39.80	42.17



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	4.7633	0.7576	-0.0194	6.5110	-0.4156	0.99	0.21	0.8
SI	0.1921	1.2010	-0.0100	-2.3009	-0.2331	0.99	0.38	1.4

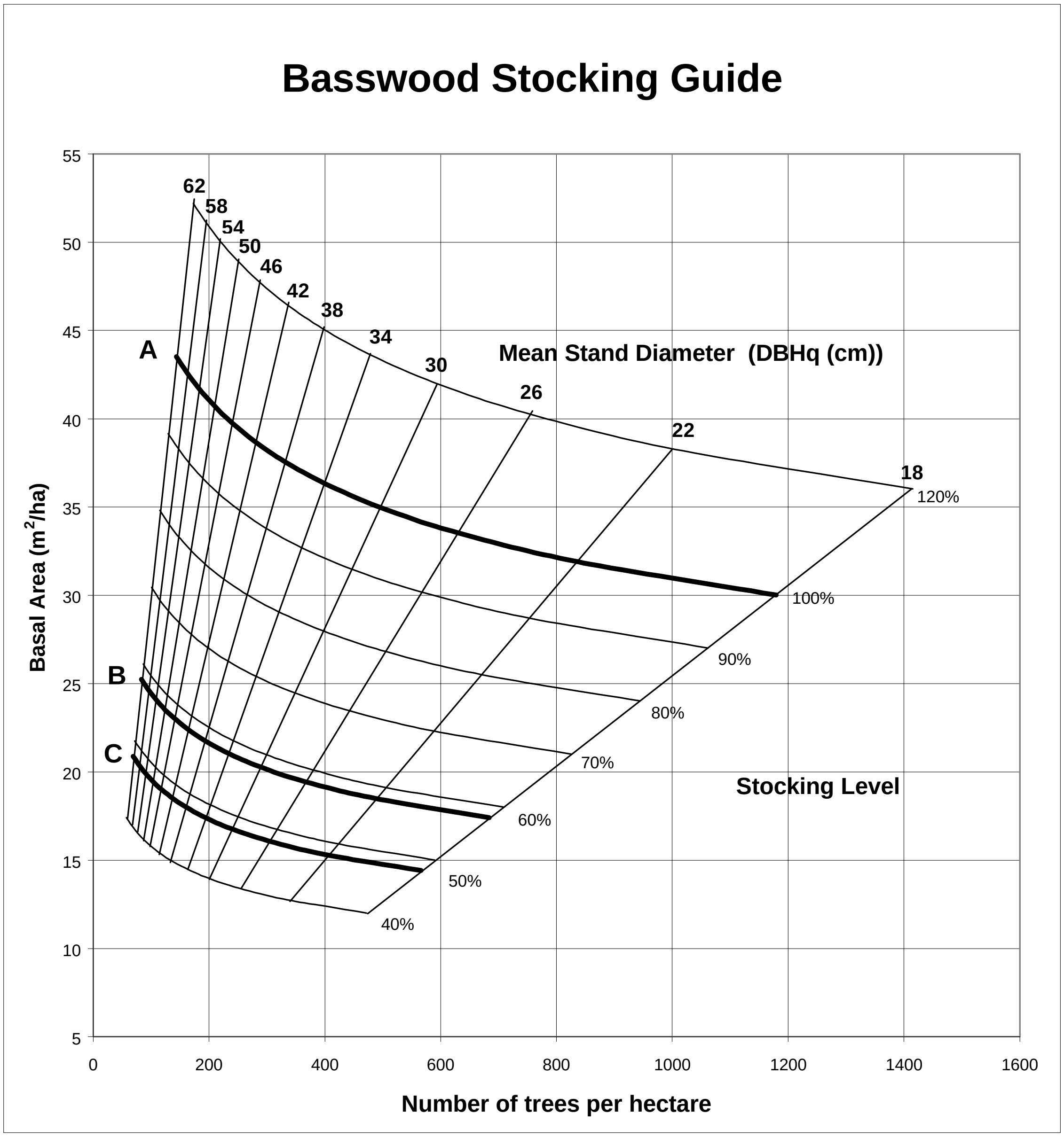
Data Source: *Carmean 1978.* *Northwest Wisconsin and Upper Michigan.* *122 plots having 483 dominant and Codominant trees.* *Stem analysis, nonlinear regression, polymorphic.* ***Add 4 years to dbh age to obtain total age.***



Cull = $\mathbf{0.0012 \times Stand\ Age^2 - 0.0749 \times Stand\ Age + 2.9935}$

Data Source: Basham, J.T. 1991. 140 Trees

Cull as a % of Gross Merchantable Volume					
Age	**%**	**Age**	**%**	**Age**	**%**
20	1.70	105	8.36	190	32.08
25	1.80	110	9.27	195	34.02
30	1.83	115	10.25	200	36.01
35	1.84	120	11.29		
40	1.92	125	12.38		
45	2.05	130	13.54		
50	2.25	135	14.75		
55	2.50	140	16.03		
60	2.82	145	17.36		
65	3.20	150	18.76		
70	3.63	155	20.21		
75	4.13	160	21.73		
80	4.68	165	23.31		
85	5.30	170	24.94		
90	5.97	175	26.64		
95	6.71	180	28.39		
100	7.50	185	30.21		



(from Crow and Erdman)

	120%		A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**	**Trees # ha**	**BA m2/ha**
18	1416	36.02	1180	30.02	1062	27.02	944	24.02	826	21.01	684	17.41	590	15.01	566	14.41
22	1006	38.26	839	31.88	755	28.69	671	25.51	587	22.32	486	18.49	419	15.94	403	15.30
26	758	40.23	631	33.52	568	30.17	505	26.82	442	23.47	366	19.44	316	16.76	303	16.09
30	594	41.99	495	34.99	446	31.49	396	27.99	347	24.49	287	20.30	248	17.50	238	16.80
34	480	43.60	400	36.33	360	32.70	320	29.07	280	25.43	232	21.07	200	18.17	192	17.44
38	397	45.08	331	37.56	298	33.81	265	30.05	232	26.30	192	21.79	166	18.78	159	18.03
42	335	46.45	279	38.71	251	34.84	224	30.97	196	27.10	162	22.45	140	19.35	134	18.58
46	287	47.74	239	39.78	215	35.80	191	31.82	168	27.85	139	23.07	120	19.89	115	19.09
50	249	48.95	208	40.79	187	36.71	166	32.63	145	28.55	120	23.66	104	20.39	100	19.58
54	219	50.09	182	41.74	164	37.57	146	33.39	128	29.22	106	24.21	91	20.87	87	20.04
58	194	51.17	161	42.65	145	38.38	129	34.12	113	29.85	94	24.73	81	21.32	77	20.47
62	173	52.21	144	43.51	130	39.16	115	34.81	101	30.46	84	25.23	72	21.75	69	20.88

Basswood Standard Volume Table (m^3)

Dbh	Total Tree Height (m)													
(cm)	4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0137	0.0203	0.0267	0.0329	0.0389	0.0447	0.0504	0.0559	0.0613	0.0666	0.0717	0.0766	0.0815	0.0862
12	0.0198	0.0292	0.0384	0.0473	0.0560	0.0644	0.0726	0.0806	0.0883	0.0959	0.1032	0.1104	0.1173	0.1241
14	0.0269	0.0398	0.0523	0.0644	0.0762	0.0877	0.0988	0.1097	0.1202	0.1305	0.1405	0.1502	0.1597	0.1690
16	0.0352	0.0520	0.0683	0.0841	0.0995	0.1145	0.1291	0.1432	0.1570	0.1704	0.1835	0.1962	0.2086	0.2207
18	0.0445	0.0658	0.0864	0.1065	0.1260	0.1449	0.1634	0.1813	0.1987	0.2157	0.2322	0.2483	0.2640	0.2793
20	0.0550	0.0812	0.1067	0.1315	0.1555	0.1789	0.2017	0.2238	0.2453	0.2663	0.2867	0.3066	0.3260	0.3448
22	0.0665	0.0983	0.1291	0.1591	0.1882	0.2165	0.2440	0.2708	0.2968	0.3222	0.3469	0.3710	0.3944	0.4173
24	0.0791	0.1170	0.1537	0.1893	0.2240	0.2577	0.2904	0.3223	0.3533	0.3834	0.4128	0.4415	0.4694	0.4966
26	0.0929	0.1373	0.1804	0.2222	0.2629	0.3024	0.3408	0.3782	0.4146	0.4500	0.4845	0.5181	0.5509	0.5828
28		0.1592	0.2092	0.2577	0.3049	0.3507	0.3953	0.4386	0.4808	0.5219	0.5619	0.6009	0.6389	0.6759
30		0.1828	0.2401	0.2958	0.3500	0.4026	0.4538	0.5035	0.5520	0.5991	0.6451	0.6898	0.7334	0.7759
32				0.3366	0.3982	0.4581	0.5163	0.5729	0.6280	0.6817	0.7339	0.7848	0.8345	0.8828
34				0.3800	0.4495	0.5171	0.5828	0.6468	0.7090	0.7696	0.8285	0.8860	0.9420	0.9966
36				0.4260	0.5039	0.5797	0.6534	0.7251	0.7948	0.8628	0.9289	0.9933	1.0561	1.1173
38					0.5615	0.6459	0.7280	0.8079	0.8856	0.9613	1.0350	1.1067	1.1767	1.2449
40					0.6222	0.7157	0.8067	0.8952	0.9813	1.0651	1.1468	1.2263	1.3038	1.3794
42						0.7891	0.8894	0.9869	1.0819	1.1743	1.2643	1.3520	1.4375	1.5208
44							0.9761	1.0832	1.1874	1.2888	1.3876	1.4838	1.5776	1.6691
46							1.0668	1.1839	1.2977	1.4086	1.5166	1.6218	1.7243	1.8243
48							1.1616	1.2890	1.4131	1.5338	1.6514	1.7659	1.8775	1.9863
50							1.2604	1.3987	1.5333	1.6643	1.7918	1.9161	2.0372	2.1553
52							1.3633	1.5128	1.6584	1.8001	1.9380	2.0725	2.2035	2.3312
54								1.6314	1.7884	1.9412	2.0900	2.2350	2.3762	2.5140
56								1.7545	1.9233	2.0876	2.2477	2.4036	2.5555	2.7036
58									2.0632	2.2394	2.4111	2.5783	2.7413	2.9002
60									2.2079	2.3965	2.5802	2.7592	2.9336	3.1036
62									2.3575	2.5590	2.7551	2.9462	3.1325	3.3140
64										2.7267	2.9357	3.1394	3.3378	3.5313
66										2.8998	3.1221	3.3386	3.5497	3.7554
68										3.0782	3.3142	3.5440	3.7681	3.9865
70										3.2619	3.5120	3.7556	3.9930	4.2244
72										3.4510	3.7155	3.9733	4.2244	4.4692
74										3.6454	3.9248	4.1971	4.4624	4.7210

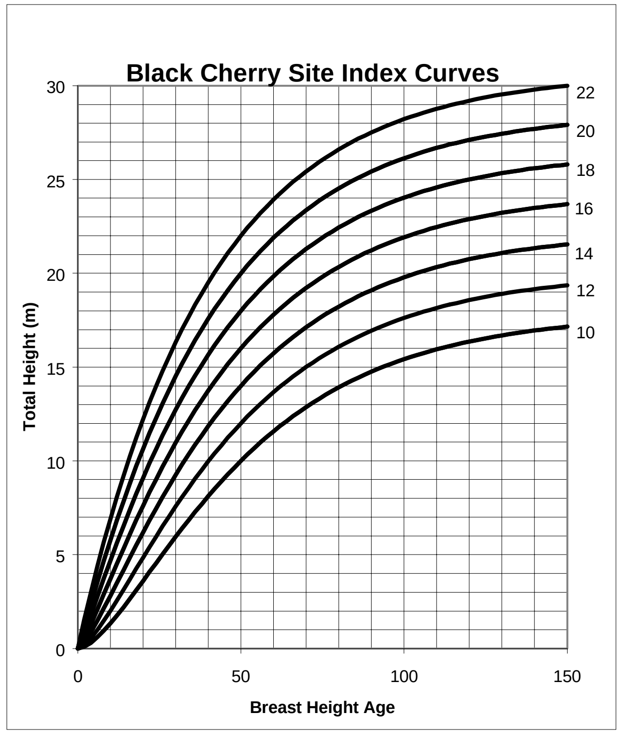
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.145)^2 / (0.948+(0.3048*401.456/Height))$ +/- 25.5% Accuracy

——— Denotes range of data 140 Trees

Black Cherry Growth & Yield Factsheet

Age	Site Index 10	12	14	16	18	20	22
5	0.5	0.8	1.2	1.7	2.3	2.9	3.7
10	1.3	2.0	2.8	3.7	4.7	5.8	6.9
15	2.4	3.4	4.5	5.7	7.0	8.3	9.7
20	3.6	4.8	6.2	7.6	9.1	10.6	12.2
25	4.8	6.2	7.8	9.4	11.0	12.7	14.4
30	6.0	7.6	9.3	11.0	12.7	14.5	16.3
35	7.1	8.8	10.6	12.4	14.3	16.1	18.0
40	8.1	10.0	11.9	13.8	15.7	17.6	19.5
45	9.1	11.0	13.0	14.9	16.9	18.9	20.8
50	10.0	12.0	14.0	16.0	18.0	20.0	22.0
55	10.8	12.9	14.9	16.9	19.0	21.0	23.0
60	11.6	13.7	15.7	17.8	19.8	21.9	23.9
65	12.3	14.4	16.5	18.5	20.6	22.7	24.7
70	12.9	15.0	17.1	19.2	21.3	23.4	25.4
75	13.4	15.6	17.7	19.8	21.9	24.0	26.0
80	13.9	16.1	18.2	20.3	22.4	24.5	26.6
85	14.4	16.5	18.7	20.8	22.9	25.0	27.1
90	14.8	16.9	19.1	21.2	23.3	25.4	27.5
95	15.1	17.3	19.5	21.6	23.7	25.8	27.9
100	15.4	17.6	19.8	21.9	24.0	26.1	28.2
105	15.7	17.9	20.1	22.2	24.3	26.4	28.5
110	15.9	18.2	20.3	22.5	24.6	26.7	28.8
115	16.2	18.4	20.6	22.7	24.8	26.9	29.0
120	16.4	18.6	20.7	22.9	25.0	27.1	29.2
125	16.5	18.7	20.9	23.1	25.2	27.3	29.4
130	16.7	18.9	21.1	23.2	25.3	27.4	29.5
135	16.8	19.0	21.2	23.4	25.5	27.6	29.7
140	16.9	19.2	21.3	23.5	25.6	27.7	29.8
145	17.1	19.3	21.4	23.6	25.7	27.8	29.9
150	17.1	19.4	21.5	23.7	25.8	27.9	30.0



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	5.0844	0.6974	-0.0250	20.7996	-0.7114	0.99	0.49	1.7
SI	0.1738	1.2707	-0.0110	-3.5467	-0.3823	0.98	0.68	2.2

Data Source: Carmean 1978

Lake States Data. Number of trees used for equation derivation unknown.
Add 4 Years to breast-height age to get total age.

Black Cherry Standard Volume Table (m^3)

Dbh	Total Tree Height (m)													
(cm)	4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0144	0.0217	0.0289	0.0360	0.0432	0.0504	0.0576	0.0647	0.0719	0.0790	0.0862	0.0933	0.1004	0.1076
12	0.0208	0.0312	0.0416	0.0519	0.0623	0.0726	0.0829	0.0932	0.1035	0.1138	0.1241	0.1344	0.1446	0.1549
14	0.0283	0.0424	0.0566	0.0707	0.0847	0.0988	0.1129	0.1269	0.1409	0.1549	0.1689	0.1829	0.1969	0.2108
16	0.0370	0.0554	0.0739	0.0923	0.1107	0.1291	0.1474	0.1657	0.1841	0.2024	0.2206	0.2389	0.2571	0.2753
18	0.0468	0.0702	0.0935	0.1168	0.1401	0.1633	0.1866	0.2098	0.2330	0.2561	0.2792	0.3023	0.3254	0.3485
20		0.0866	0.1154	0.1442	0.1729	0.2017	0.2303	0.2590	0.2876	0.3162	0.3447	0.3733	0.4018	0.4302
22		0.1048	0.1397	0.1745	0.2093	0.2440	0.2787	0.3134	0.3480	0.3826	0.4171	0.4517	0.4861	0.5206
24			0.1662	0.2076	0.2490	0.2904	0.3317	0.3729	0.4141	0.4553	0.4964	0.5375	0.5785	0.6195
26			0.1951	0.2437	0.2923	0.3408	0.3893	0.4377	0.4860	0.5344	0.5826	0.6308	0.6790	0.7271
28				0.2826	0.3390	0.3952	0.4514	0.5076	0.5637	0.6197	0.6757	0.7316	0.7874	0.8432
30				0.3244	0.3891	0.4537	0.5182	0.5827	0.6471	0.7114	0.7757	0.8398	0.9040	0.9680
32				0.3691	0.4427	0.5162	0.5896	0.6630	0.7363	0.8094	0.8825	0.9556	1.0285	1.1014
34				0.4167	0.4998	0.5828	0.6657	0.7485	0.8312	0.9138	0.9963	1.0787	1.1611	1.2433
36				0.4672	0.5603	0.6533	0.7463	0.8391	0.9318	1.0244	1.1170	1.2094	1.3017	1.3939
38				0.5205	0.6243	0.7280	0.8315	0.9349	1.0382	1.1414	1.2445	1.3475	1.4503	1.5531
40					0.6918	0.8066	0.9213	1.0359	1.1504	1.2647	1.3790	1.4931	1.6070	1.7209
42					0.7627	0.8893	1.0158	1.1421	1.2683	1.3944	1.5203	1.6461	1.7718	1.8973
44					0.8370	0.9760	1.1148	1.2535	1.3920	1.5303	1.6685	1.8066	1.9445	2.0823
46						1.0667	1.2185	1.3700	1.5214	1.6726	1.8237	1.9746	2.1253	2.2759
48							1.3267	1.4917	1.6566	1.8212	1.9857	2.1500	2.3141	2.4781
50							1.4396	1.6186	1.7975	1.9762	2.1546	2.3329	2.5110	2.6889
52							1.5570	1.7507	1.9442	2.1374	2.3305	2.5233	2.7159	2.9083
54								1.8880	2.0966	2.3050	2.5132	2.7211	2.9288	3.1363
56								2.0304	2.2548	2.4789	2.7028	2.9264	3.1498	3.3729
58									2.4187	2.6591	2.8993	3.1392	3.3788	3.6182
60									2.5884	2.8457	3.1027	3.3594	3.6158	3.8720
62									2.7638	3.0385	3.3130	3.5871	3.8609	4.1344
64									2.9450	3.2377	3.5302	3.8222	4.1140	4.4055
66									3.1320	3.4433	3.7542	4.0649	4.3752	4.6851
68									3.3246	3.6551	3.9852	4.3150	4.6443	4.9734
70										3.8733	4.2231	4.5725	4.9215	5.2702
72											4.4678	4.8375	5.2068	5.5757
74											4.7195	5.1100	5.5001	5.8897

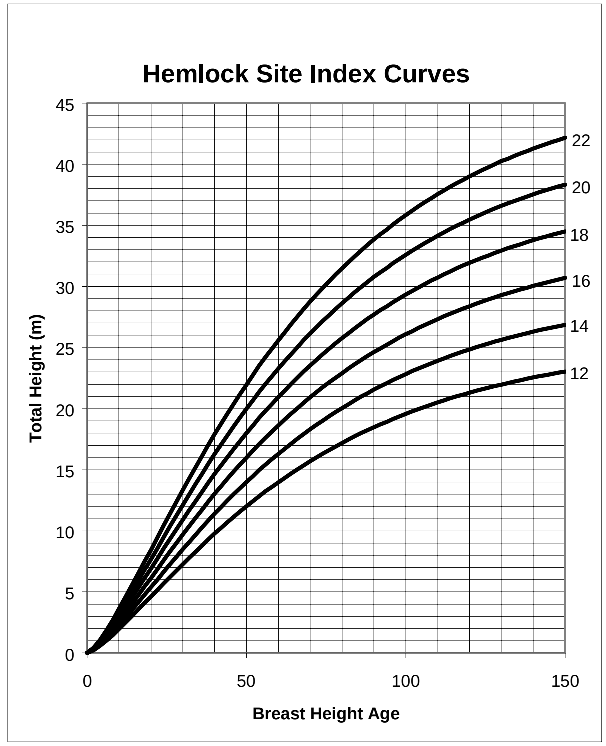
Honer's (1983) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.145)^2 / (0.033+(0.3048*393.336/Height))$ +/- 13 +/- 19.8 % Accuracy

21 Trees

Eastern Hemlock Growth & Yield Factsheet

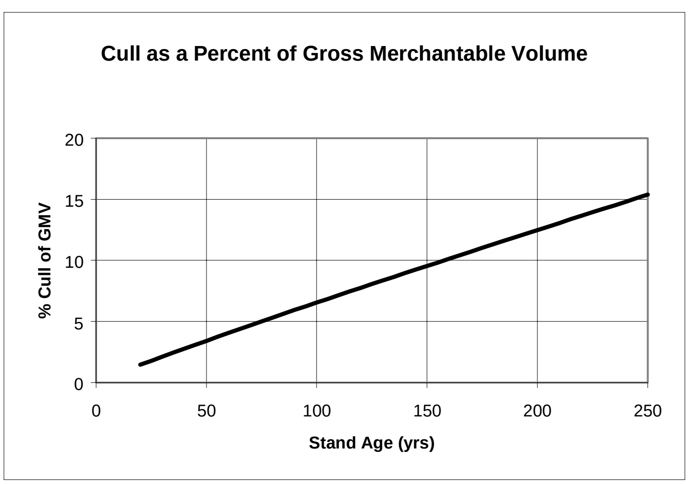
Age	Site Index 12	14	16	18	20	22
5	0.57	0.87	1.22	1.63	2.09	2.59
10	1.68	2.33	3.05	3.83	4.66	5.53
15	3.02	3.99	5.02	6.10	7.22	8.36
20	4.45	5.69	6.97	8.29	9.63	10.99
25	5.88	7.34	8.83	10.34	11.85	13.38
30	7.28	8.91	10.57	12.22	13.88	15.53
35	8.59	10.38	12.16	13.94	15.70	17.45
40	9.81	11.72	13.61	15.48	17.33	19.17
45	10.94	12.94	14.92	16.87	18.79	20.69
50	11.96	14.05	16.09	18.10	20.08	22.03
55	12.89	15.04	17.14	19.20	21.23	23.22
60	13.72	15.92	18.07	20.18	22.24	24.26
65	14.47	16.72	18.90	21.04	23.13	25.18
70	15.14	17.42	19.64	21.80	23.92	25.99
75	15.73	18.04	20.29	22.47	24.61	26.70
80	16.25	18.59	20.86	23.07	25.22	27.33
85	16.72	19.08	21.36	23.59	25.76	27.88
90	17.13	19.51	21.81	24.04	26.23	28.36
95	17.49	19.88	22.20	24.45	26.64	28.78
100	17.81	20.22	22.54	24.80	27.00	29.15
105	18.10	20.51	22.84	25.11	27.32	29.47
110	18.34	20.77	23.11	25.38	27.59	29.76
115	18.56	20.99	23.34	25.62	27.84	30.00
120	18.75	21.19	23.54	25.83	28.05	30.22
125	18.92	21.36	23.72	26.01	28.24	30.41
130	19.07	21.51	23.88	26.17	28.40	30.58
135	19.20	21.65	24.01	26.31	28.54	30.72
140	19.31	21.76	24.13	26.43	28.67	30.85
145	19.41	21.87	24.24	26.54	28.78	30.96
150	19.50	21.95	24.33	26.63	28.87	31.06



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	2.1419	0.9979	-0.0175	1.4086	-0.0008	0.99	0.15	0.5
SI	0.2172	1.1309	-0.0105	-1.9120	-0.1327	0.99	0.37	1.0

Data Source: *Frothingham 1915* *Based on average of "maximum" height growth curves from stands in New York, Mich., and S. Appalachan Mountains* ***Add 6years to dbh age to obtain total age.***

Number of plots and dominant trees not given.

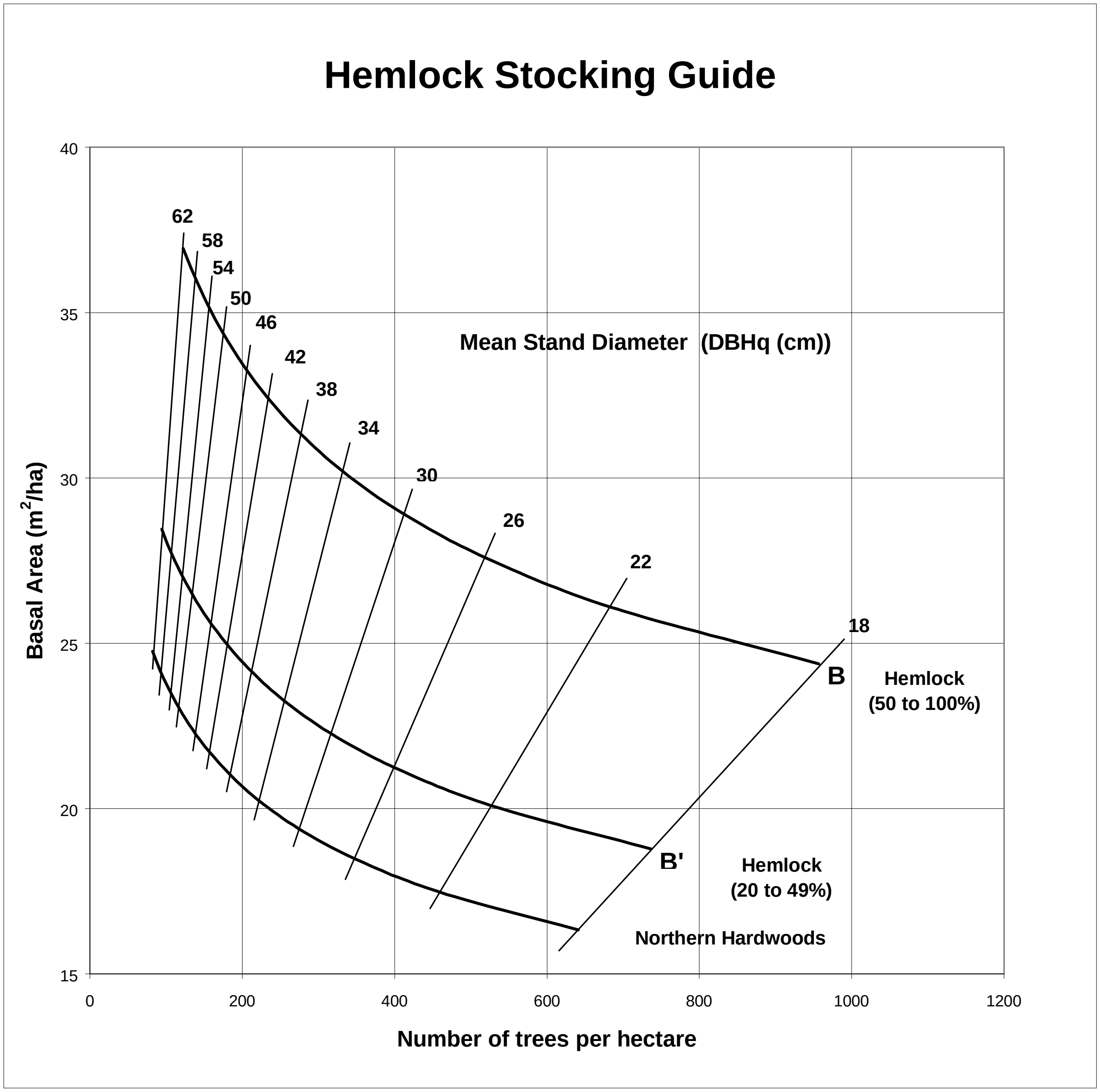


Cull = = 0.0892 * Stand Age$^{0.9326}$

Data Source: Basham, J.T. 1991. 387 Trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%	Age	%
20	1.46	105	6.84	190	11.90
25	1.80	110	7.15	195	12.19
30	2.13	115	7.45	200	12.48
35	2.46	120	7.75	205	12.77
40	2.78	125	8.05	210	13.06
45	3.11	130	8.35	215	13.35
50	3.43	135	8.65	220	13.64
55	3.74	140	8.95	225	13.93
60	4.06	145	9.25	230	14.22
65	4.38	150	9.55	235	14.51
70	4.69	155	9.84	240	14.80
75	5.00	160	10.14	245	15.08
80	5.31	165	10.43	250	15.37
85	5.62	170	10.73	255	15.66
90	5.93	175	11.02	260	15.94
95	6.23	180	11.31	265	16.23
100	6.54	185	11.61	270	16.51



(Based on Tubbs 1977)

	B Line Hemlock (50 - 100%)		B' Line Hemlock (20 - 49%)		Northern Hardwoods	
DBHq (cm)	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**
18	957	24.4	737	18.8	641	16.3
22	686	26.1	528	20.1	459	17.5
26	519	27.6	400	21.2	348	18.5
30	409	28.9	315	22.3	274	19.4
34	333	30.2	256	23.2	223	20.2
38	276	31.3	213	24.1	185	21.0
42	234	32.4	180	25.0	157	21.7
46	201	33.4	155	25.7	135	22.4
50	175	34.4	135	26.5	117	23.0
54	154	35.3	119	27.2	103	23.6
58	137	36.1	105	27.8	92	24.2
62	123	36.9	94	28.4	82	24.8

Eastern Hemlock Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0229	0.0300	0.0367	0.0433	0.0496	0.0556	0.0615	0.0672	0.0726	0.0779	0.0830	0.0880	0.0927
12	0.0224	0.0330	0.0431	0.0529	0.0623	0.0714	0.0801	0.0886	0.0967	0.1046	0.1122	0.1195	0.1267	0.1335
14	0.0305	0.0449	0.0587	0.0720	0.0848	0.0972	0.1091	0.1205	0.1316	0.1423	0.1527	0.1627	0.1724	0.1818
16	0.0399	0.0587	0.0767	0.0941	0.1108	0.1269	0.1425	0.1574	0.1719	0.1859	0.1994	0.2125	0.2252	0.2374
18	0.0505	0.0742	0.0971	0.1191	0.1402	0.1606	0.1803	0.1993	0.2176	0.2353	0.2524	0.2690	0.2850	0.3005
20	0.0623	0.0917	0.1199	0.1470	0.1731	0.1983	0.2226	0.2460	0.2686	0.2905	0.3116	0.3320	0.3518	0.3710
22	0.0754	0.1109	0.1450	0.1779	0.2095	0.2399	0.2693	0.2977	0.3250	0.3515	0.3770	0.4018	0.4257	0.4489
24	0.0897	0.1320	0.1726	0.2117	0.2493	0.2856	0.3205	0.3543	0.3868	0.4183	0.4487	0.4781	0.5066	0.5342
26	0.1053	0.1549	0.2026	0.2484	0.2926	0.3351	0.3762	0.4158	0.4540	0.4909	0.5266	0.5611	0.5946	0.6269
28	0.1222	0.1796	0.2349	0.2881	0.3393	0.3887	0.4363	0.4822	0.5265	0.5693	0.6107	0.6508	0.6895	0.7271
30		0.2062	0.2697	0.3307	0.3895	0.4462	0.5008	0.5535	0.6044	0.6536	0.7011	0.7471	0.7916	0.8346
32		0.2346	0.3068	0.3763	0.4432	0.5077	0.5698	0.6298	0.6877	0.7436	0.7977	0.8500	0.9006	0.9496
34			0.3464	0.4248	0.5003	0.5731	0.6433	0.7110	0.7763	0.8395	0.9005	0.9596	1.0167	1.0721
36				0.4763	0.5609	0.6425	0.7212	0.7971	0.8704	0.9412	1.0096	1.0758	1.1399	1.2019
38				0.5306	0.6250	0.7159	0.8035	0.8881	0.9698	1.0486	1.1249	1.1987	1.2700	1.3391
40				0.5880	0.6925	0.7932	0.8903	0.9840	1.0745	1.1619	1.2464	1.3282	1.4072	1.4838
42					0.7635	0.8745	0.9816	1.0849	1.1847	1.2810	1.3742	1.4643	1.5515	1.6359
44					0.8379	0.9598	1.0773	1.1907	1.3002	1.4059	1.5082	1.6071	1.7028	1.7954
46					0.9158	1.0490	1.1775	1.3014	1.4211	1.5367	1.6484	1.7565	1.8611	1.9624
48					0.9972	1.1422	1.2821	1.4170	1.5473	1.6732	1.7949	1.9125	2.0264	2.1367
50					1.0820	1.2394	1.3911	1.5376	1.6789	1.8155	1.9475	2.0752	2.1988	2.3185
52						1.3405	1.5047	1.6630	1.8159	1.9637	2.1065	2.2446	2.3782	2.5077
54						1.4456	1.6226	1.7934	1.9583	2.1176	2.2716	2.4206	2.5647	2.7043
56						1.5547	1.7450	1.9287	2.1061	2.2774	2.4430	2.6032	2.7582	2.9083
58							1.8719	2.0689	2.2592	2.4430	2.6206	2.7924	2.9587	3.1197
60							2.0032	2.2141	2.4177	2.6143	2.8045	2.9883	3.1663	3.3386
62								2.3642	2.5815	2.7915	2.9945	3.1909	3.3809	3.5649
64										2.9745	3.1909	3.4001	3.6025	3.7986
66										3.1634	3.3934	3.6159	3.8312	4.0397
68										3.3580	3.6022	3.8384	4.0669	4.2882
70										3.5584	3.8172	4.0675	4.3097	4.5442
72										3.7647	4.0384	4.3032	4.5595	4.8076
74										3.9767	4.2659	4.5456	4.8163	5.0784

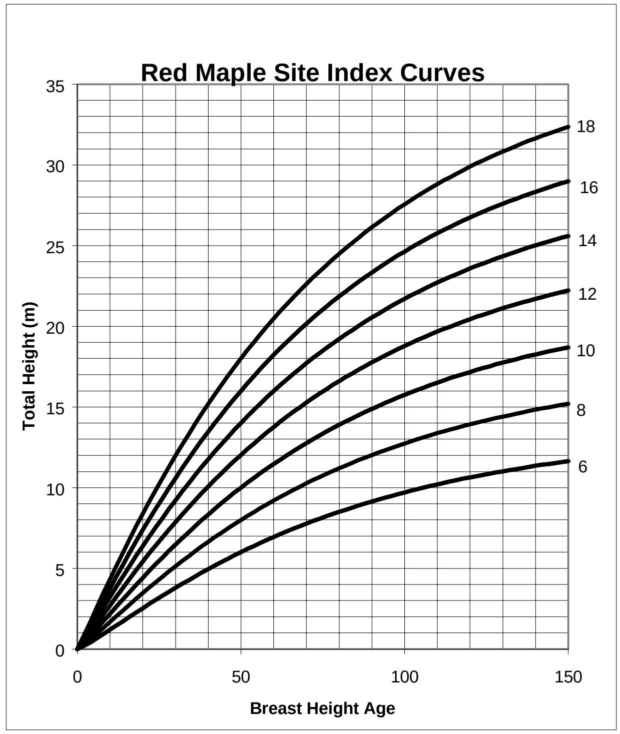
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.155)^2 / (1.112+(0.3048 \cdot 350.092/Height))$ +/- 23.6% Accuracy

——— Denotes range of data   383 Trees

Red Maple Growth & Yield Factsheet

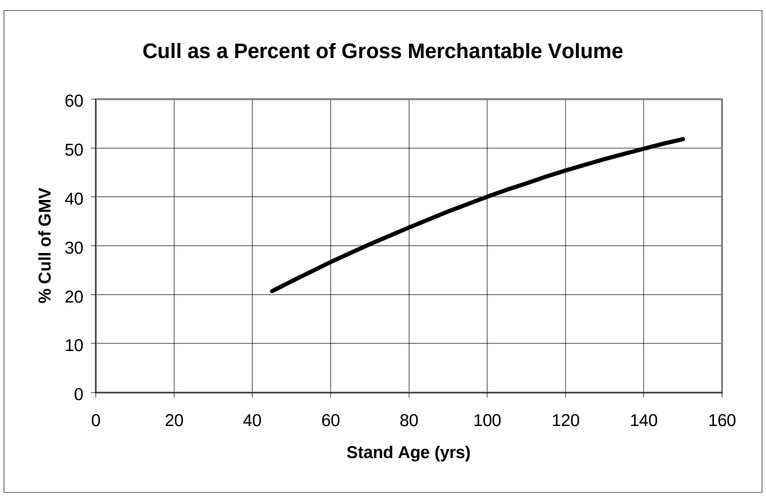
Age	Site Index 6	8	10	12	14	16	18
5	0.5	0.8	1.0	1.3	1.6	1.9	2.1
10	1.2	1.7	2.2	2.7	3.2	3.8	4.3
15	1.9	2.6	3.3	4.1	4.8	5.6	6.4
20	2.5	3.5	4.4	5.4	6.4	7.4	8.4
25	3.2	4.3	5.5	6.7	7.8	9.0	10.2
30	3.8	5.1	6.5	7.9	9.2	10.6	12.0
35	4.4	5.9	7.4	9.0	10.5	12.1	13.6
40	5.0	6.6	8.3	10.1	11.8	13.5	15.2
45	5.5	7.3	9.2	11.1	12.9	14.8	16.6
50	6.0	8.0	10.0	12.0	14.0	16.0	18.0
55	6.5	8.6	10.8	12.9	15.0	17.1	19.3
60	6.9	9.2	11.5	13.8	16.0	18.2	20.5
65	7.4	9.7	12.1	14.5	16.9	19.2	21.6
70	7.8	10.3	12.8	15.3	17.7	20.2	22.6
75	8.1	10.7	13.3	16.0	18.5	21.0	23.6
80	8.5	11.2	13.9	16.6	19.2	21.9	24.5
85	8.8	11.6	14.4	17.2	19.9	22.6	25.3
90	9.1	12.0	14.9	17.8	20.5	23.3	26.1
95	9.4	12.4	15.3	18.3	21.1	24.0	26.9
100	9.7	12.7	15.7	18.8	21.7	24.6	27.6
105	10.0	13.1	16.1	19.2	22.2	25.2	28.2
110	10.2	13.4	16.5	19.7	22.7	25.8	28.8
115	10.4	13.7	16.9	20.1	23.2	26.3	29.4
120	10.6	13.9	17.2	20.4	23.6	26.7	29.9
125	10.8	14.2	17.5	20.8	24.0	27.2	30.4
130	11.0	14.4	17.8	21.1	24.3	27.6	30.8
135	11.2	14.6	18.0	21.4	24.7	28.0	31.3
140	11.3	14.8	18.3	21.7	25.0	28.3	31.6
145	11.5	15.0	18.5	22.0	25.3	28.7	32.0
150	11.6	15.2	18.7	22.2	25.6	29.0	32.4



Ht=[b1*(SI*.3048^b2)*(1-EXP^b3 *Age)^b4 *(SI*.3048^b5)] *.3048	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	2.9435	0.9132	-0.0141	1.6580	-0.1095	0.99	0.15	0.6
SI	0.3263	1.0634	-0.0106	-1.2573	-0.0646	0.99	0.16	0.7

Data Source: Carmean 1978

Northern Wisconsin and Upper Michigan. 114 Plots having 438 dominant and codominant trees. Stem analysis, nonlinear regression, polymorphic. Add 4 years to obtain total age.



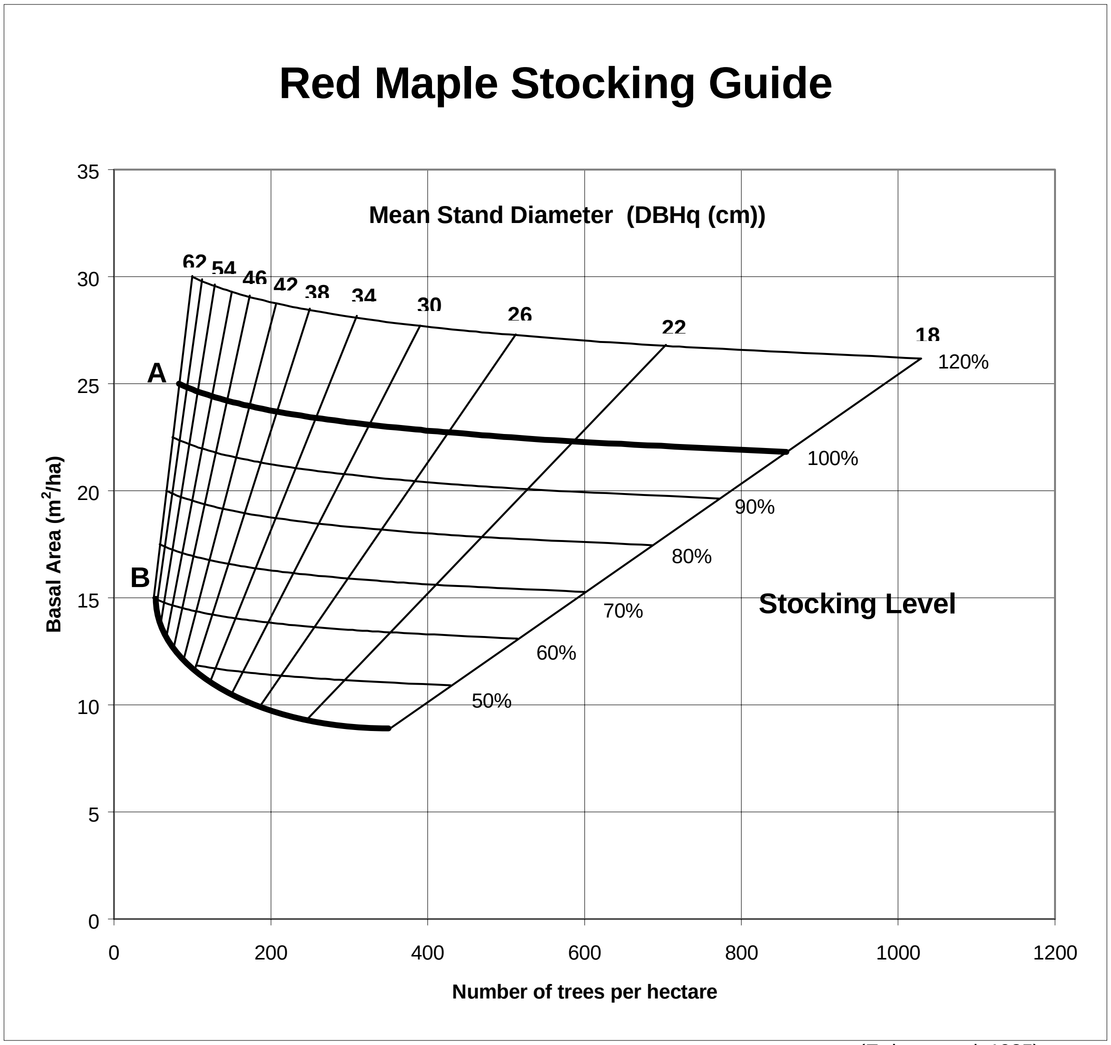
Cull = -0.0011 * Stand Age² + 0.5101 * Stand Age

$$\text{Cull} = -0.0011 * \text{Stand Age}^2 + 0.5101 * \text{Stand Age}$$

Data Source: Basham, J.T. 1991. 66 trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%
20	9.76	105	41.43
25	12.07	110	42.80
30	14.31	115	44.11
35	16.51	120	45.37
40	18.64	125	46.58
45	20.73	130	47.72
50	22.76	135	48.82
55	24.73	140	49.85
60	26.65	145	50.84
65	28.51	150	51.77
70	30.32		
75	32.07		
80	33.77		
85	35.41		
90	37.00		
95	38.53		
100	40.01		



(Erdman et al. 1985)

	120%		A Line		90%		80%		60%		50%	
DBHq (cm)	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**
18	1029	26.2	858	21.8	772	19.6	686	17.5	515	13.1	429	10.9
22	704	26.8	587	22.3	528	20.1	470	17.8	352	13.4	293	11.2
26	514	27.3	428	22.7	385	20.4	342	18.2	257	13.6	214	11.4
30	392	27.7	327	23.1	294	20.8	261	18.5	196	13.8	163	11.5
34	309	28.1	258	23.4	232	21.1	206	18.7	155	14.0	129	11.7
38	251	28.4	209	23.7	188	21.3	167	19.0	125	14.2	104	11.8
42	208	28.7	173	24.0	156	21.6	138	19.2	104	14.4	86	12.0
46	175	29.0	146	24.2	131	21.8	116	19.4	87	14.5	73	12.1
50	149	29.3	124	24.4	112	22.0	100	19.5	75	14.6	62	12.2
54	129	29.5	108	24.6	97	22.2	86	19.7	65	14.8	54	12.3
58	113	29.8	94	24.8	85	22.3	75	19.9	56	14.9	47	12.4
62	99	30.0	83	25.0	75	22.5	66	20.0	50	15.0	41	12.5

Maple Standard Volume Table (m^3)*

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0143	0.0211	0.0276	0.0340	0.0401	0.0461	0.0518	0.0574	0.0628	0.0681	0.0732	0.0781	0.0829	0.0876
12	0.0206	0.0304	0.0398	0.0489	0.0578	0.0663	0.0746	0.0827	0.0905	0.0980	0.1054	0.1125	0.1194	0.1261
14	0.0280	0.0413	0.0542	0.0666	0.0787	0.0903	0.1016	0.1125	0.1231	0.1334	0.1434	0.1531	0.1625	0.1717
16	0.0366	0.0540	0.0708	0.0870	0.1027	0.1180	0.1327	0.1470	0.1608	0.1743	0.1873	0.2000	0.2123	0.2243
18	0.0463	0.0683	0.0896	0.1101	0.1300	0.1493	0.1679	0.1860	0.2036	0.2206	0.2371	0.2531	0.2687	0.2838
20	0.0572	0.0843	0.1106	0.1360	0.1605	0.1843	0.2073	0.2297	0.2513	0.2723	0.2927	0.3125	0.3317	0.3504
22	0.0692	0.1021	0.1338	0.1645	0.1942	0.2230	0.2509	0.2779	0.3041	0.3295	0.3542	0.3781	0.4014	0.4240
24	0.0824	0.1215	0.1592	0.1958	0.2312	0.2654	0.2986	0.3307	0.3619	0.3921	0.4215	0.4500	0.4777	0.5046
26		0.1425	0.1869	0.2298	0.2713	0.3115	0.3504	0.3881	0.4247	0.4602	0.4947	0.5281	0.5606	0.5922
28		0.1653	0.2168	0.2665	0.3146	0.3612	0.4064	0.4501	0.4926	0.5337	0.5737	0.6125	0.6502	0.6868
30			0.2488	0.3059	0.3612	0.4147	0.4665	0.5167	0.5655	0.6127	0.6586	0.7031	0.7464	0.7884
32				0.3481	0.4109	0.4718	0.5308	0.5879	0.6434	0.6971	0.7493	0.8000	0.8492	0.8970
34				0.3929	0.4639	0.5326	0.5992	0.6637	0.7263	0.7870	0.8459	0.9031	0.9587	1.0127
36					0.5201	0.5971	0.6718	0.7441	0.8143	0.8823	0.9483	1.0125	1.0748	1.1353
38					0.5795	0.6653	0.7485	0.8291	0.9072	0.9831	1.0566	1.1281	1.1975	1.2649
40					0.6421	0.7372	0.8294	0.9187	1.0052	1.0893	1.1708	1.2500	1.3269	1.4016
42						0.8128	0.9144	1.0128	1.1083	1.2009	1.2908	1.3781	1.4629	1.5453
44						0.8920	1.0035	1.1116	1.2164	1.3180	1.4167	1.5125	1.6055	1.6959
46						0.9750	1.0968	1.2149	1.3294	1.4405	1.5484	1.6531	1.7548	1.8536
48						1.0616	1.1943	1.3229	1.4476	1.5685	1.6859	1.7999	1.9107	2.0183
50						1.1519	1.2959	1.4354	1.5707	1.7020	1.8294	1.9531	2.0732	2.1900
52						1.2459	1.4016	1.5525	1.6989	1.8408	1.9786	2.1124	2.2424	2.3687
54						1.3436	1.5115	1.6743	1.8321	1.9852	2.1338	2.2781	2.4182	2.5544
56						1.4449	1.6255	1.8006	1.9703	2.1349	2.2948	2.4499	2.6007	2.7471
58								1.9315	2.1135	2.2902	2.4616	2.6280	2.7897	2.9469
60								2.0670	2.2618	2.4508	2.6343	2.8124	2.9854	3.1536
62								2.2071	2.4151	2.6169	2.8128	3.0030	3.1878	3.3674
64									2.5734	2.7885	2.9972	3.1999	3.3968	3.5881
66										2.9655	3.1875	3.4030	3.6124	3.8159
68										3.1480	3.3836	3.6124	3.8346	4.0506
70										3.3358	3.5855	3.8280	4.0635	4.2924
72										3.5292	3.7934	4.0499	4.2990	4.5412
74										3.7280	4.0070	4.2780	4.5412	4.7970

Honer's (1967) Total cubic metre volume equation

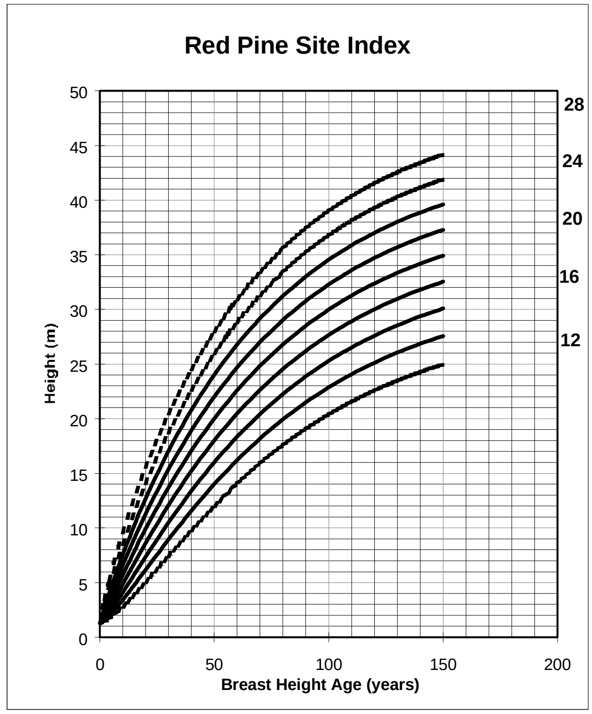
Volume (m^3) = $0.0043891*dbh^2 * (1-0.04365*0.145)^2 / (1.046+(0.3048*383.972/Height))$ +/- 30.3% Accuracy

* Volume table includes Hard and Red maple 3967 Trees

——— Denotes range of data

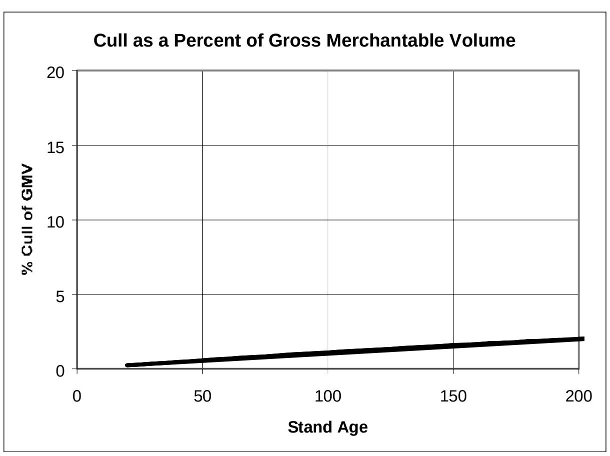
Red Pine Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24	26	28
5	1.88	2.18	2.54	2.97	3.46	4.00	4.61	5.26	5.97
10	2.81	3.41	4.10	4.86	5.69	6.58	7.54	8.54	9.59
15	3.89	4.77	5.72	6.76	7.85	9.00	10.21	11.46	12.75
20	5.05	6.16	7.35	8.60	9.91	11.27	12.67	14.10	15.58
25	6.24	7.56	8.94	10.38	11.86	13.38	14.94	16.52	18.14
30	7.44	8.94	10.49	12.08	13.70	15.36	17.04	18.74	20.47
35	8.63	10.28	11.97	13.69	15.43	17.20	18.99	20.78	22.60
40	9.79	11.57	13.38	15.21	17.05	18.91	20.79	22.66	24.55
45	10.92	12.82	14.73	16.65	18.57	20.51	22.46	24.39	26.35
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00
55	13.05	15.13	17.21	19.27	21.33	23.39	25.44	27.48	29.53
60	14.05	16.20	18.34	20.47	22.58	24.68	26.78	28.85	30.93
65	15.00	17.22	19.42	21.59	23.74	25.89	28.01	30.12	32.24
70	15.90	18.18	20.42	22.64	24.83	27.01	29.17	31.30	33.44
75	16.76	19.09	21.37	23.62	25.84	28.05	30.23	32.39	34.55
80	17.57	19.94	22.26	24.54	26.79	29.02	31.23	33.40	35.58
85	18.34	20.74	23.09	25.40	27.67	29.92	32.15	34.34	36.54
90	19.06	21.49	23.87	26.20	28.49	30.76	33.01	35.22	37.42
95	19.74	22.20	24.60	26.95	29.26	31.55	33.80	36.03	38.24
100	20.38	22.87	25.29	27.65	29.98	32.28	34.54	36.78	39.00
105	20.98	23.49	25.93	28.31	30.65	32.95	35.23	37.47	39.71
110	21.55	24.07	26.52	28.92	31.27	33.59	35.87	38.12	40.36
115	22.08	24.62	27.08	29.49	31.85	34.17	36.47	38.72	
120	22.58	25.13	27.60	30.02	32.38	34.72	37.02	39.28	
125	23.04	25.61	28.09	30.51	32.89	35.23	37.53	39.80	
130	23.48	26.05	28.55	30.98	33.35	35.70	38.01	40.28	
135	23.89	26.47	28.97	31.41	33.79	36.14	38.46		
140	24.27	26.86	29.37	31.81	34.20	36.55	38.87		
145	24.63	27.22	29.73	32.18	34.57	36.93	39.25		
150	24.96	27.56	30.08	32.53	34.93	37.29	39.61		



$Ht=1.3+[b1*(SI^{b2})*(1-EXP^{b3*Age})^{b4*(SI^{b5})}]$	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	8.3914	0.5158	-0.0145	4.8468	-0.5094	0.99	0.47	3.2

Data Source: Central Ontario Based on 42 trees from FEC plots ***Total Age = Breast Height Age + 5 years***



Cull $= -0.00001*Age^2 + 0.0121*Age$

Data Source: Discussion by Basham, J.T. 1991. 462 Trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%	Age	%
20	0.24	105	1.16	190	1.94
25	0.30	110	1.21	195	1.98
30	0.35	115	1.26	200	2.02
35	0.41	120	1.31		
40	0.47	125	1.36		
45	0.52	130	1.40		
50	0.58	135	1.45		
55	0.64	140	1.50		
60	0.69	145	1.54		
65	0.74	150	1.59		
70	0.80	155	1.64		
75	0.85	160	1.68		
80	0.90	165	1.72		
85	0.96	170	1.77		
90	1.01	175	1.81		
95	1.06	180	1.85		
100	1.11	185	1.90		

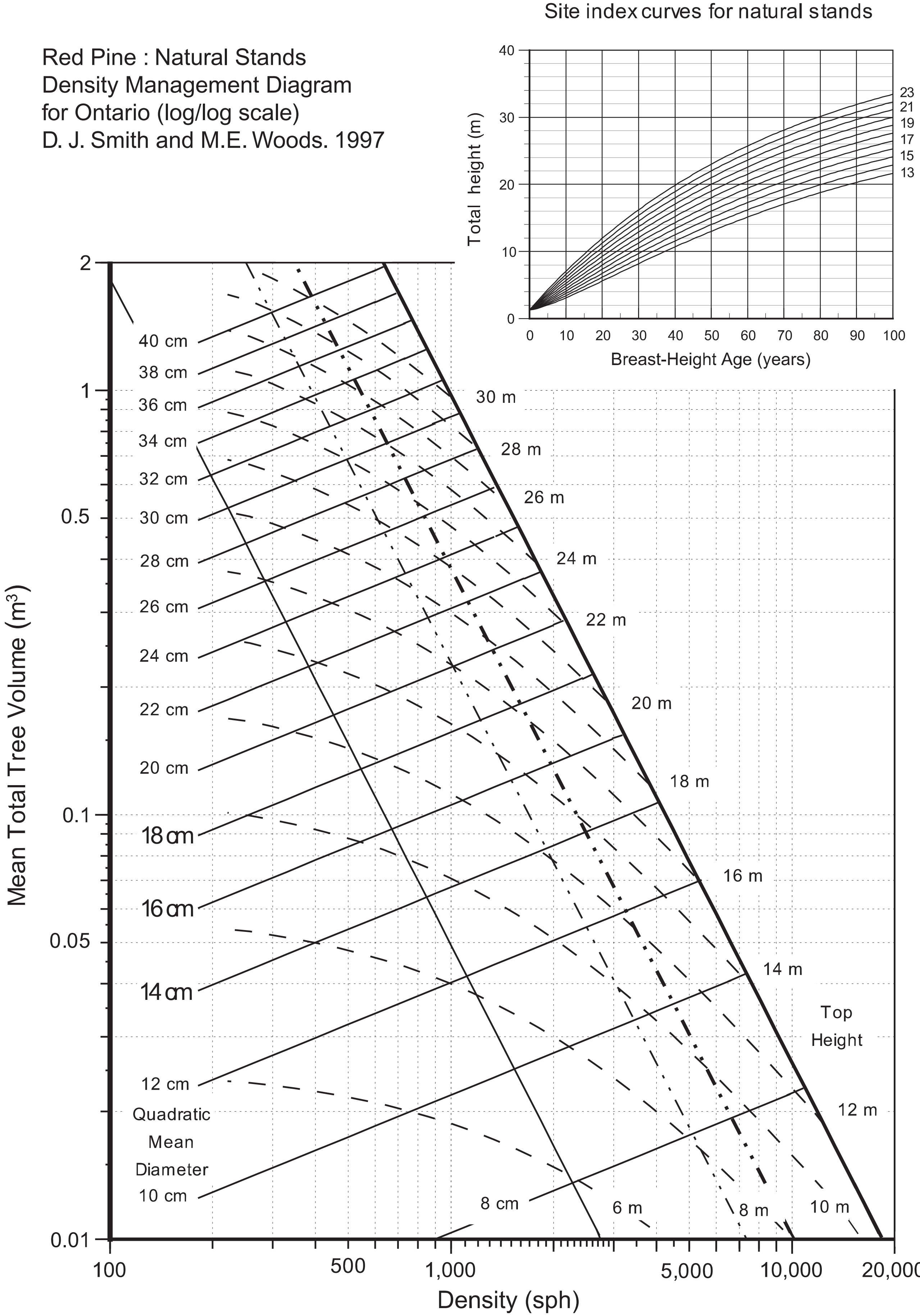
Red Pine Standard Volume Table (m^3/ha)

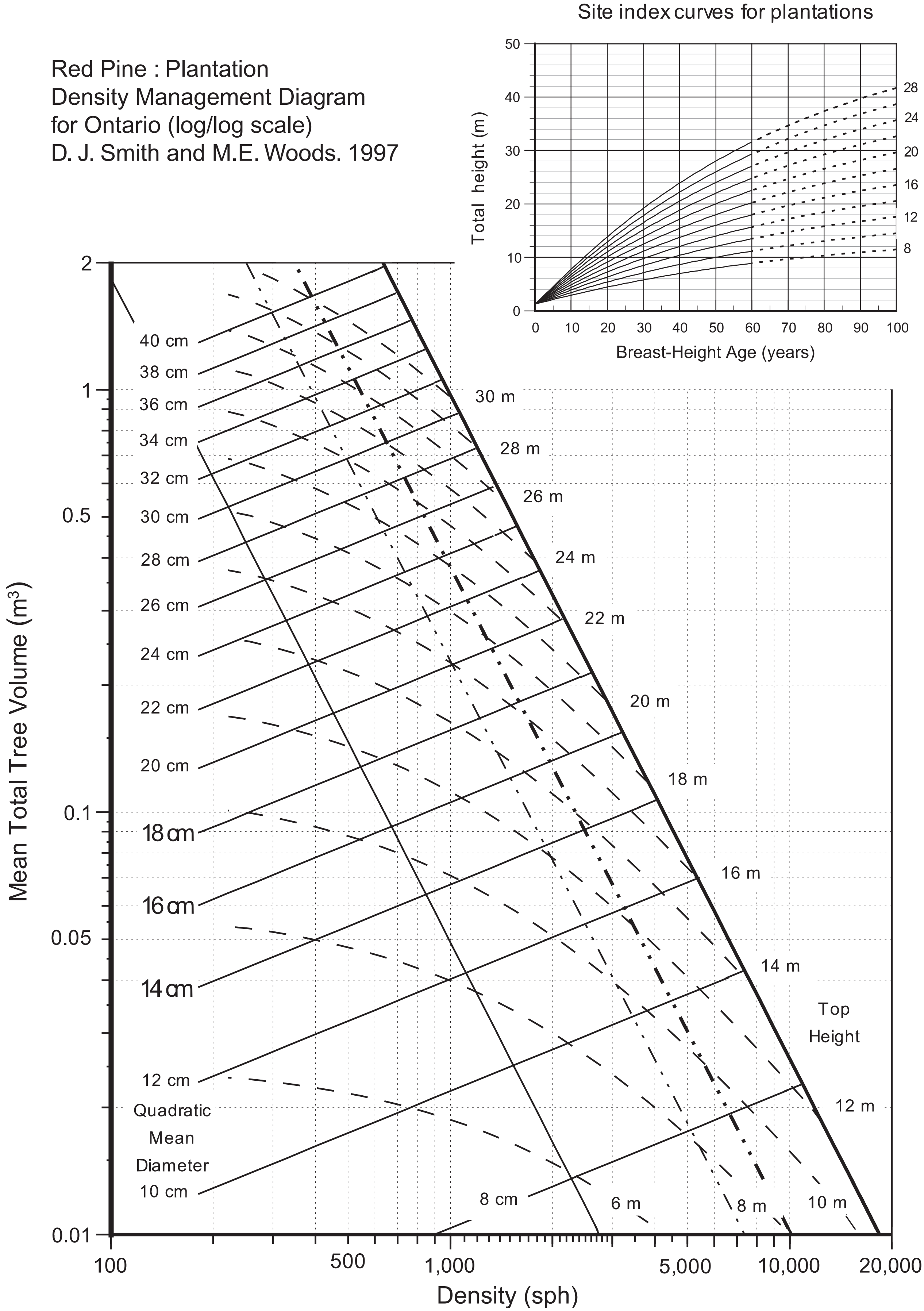
Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0231	0.0304	0.0375	0.0445	0.0512	0.0579	0.0643	0.0707					
12	0.0224	0.0332	0.0437	0.0540	0.0640	0.0738	0.0833	0.0927	0.1018	0.1106	0.1193			
14	0.0305	0.0452	0.0595	0.0735	0.0871	0.1004	0.1134	0.1261	0.1385	0.1506	0.1624	0.1740	0.1853	
16	0.0399	0.0591	0.0778	0.0960	0.1138	0.1312	0.1482	0.1647	0.1809	0.1967	0.2122	0.2273	0.2420	
18	0.0505	0.0747	0.0984	0.1215	0.1440	0.1660	0.1875	0.2085	0.2289	0.2490	0.2685	0.2876	0.3063	0.3246
20	0.0623	0.0923	0.1215	0.1500	0.1778	0.2050	0.2315	0.2574	0.2827	0.3074	0.3315	0.3551	0.3782	0.4008
22	0.0754	0.1117	0.1470	0.1815	0.2152	0.2480	0.2801	0.3114	0.3420	0.3719	0.4011	0.4297	0.4576	0.4849
24		0.1329	0.1750	0.2160	0.2561	0.2952	0.3333	0.3706	0.4070	0.4426	0.4774	0.5114	0.5446	0.5771
26		0.1559	0.2053	0.2535	0.3005	0.3464	0.3912	0.4350	0.4777	0.5194	0.5602	0.6001	0.6391	0.6773
28			0.2382	0.2940	0.3485	0.4018	0.4537	0.5044	0.5540	0.6024	0.6497	0.6960	0.7413	0.7855
30			0.2734	0.3375	0.4001	0.4612	0.5208	0.5791	0.6360	0.6916	0.7459	0.7990	0.8509	0.9017
32			0.3111	0.3840	0.4552	0.5247	0.5926	0.6589	0.7236	0.7868	0.8486	0.9091	0.9682	1.0260
34				0.4335	0.5139	0.5924	0.6690	0.7438	0.8169	0.8883	0.9580	1.0263	1.0930	1.1582
36				0.4860	0.5762	0.6641	0.7500	0.8339	0.9158	0.9958	1.0741	1.1506	1.2253	1.2985
38				0.5416	0.6420	0.7400	0.8357	0.9291	1.0204	1.1096	1.1967	1.2819	1.3653	1.4468
40					0.7113	0.8199	0.9259	1.0295	1.1306	1.2294	1.3260	1.4204	1.5128	1.6031
42					0.7842	0.9040	1.0208	1.1350	1.2465	1.3554	1.4619	1.5660	1.6678	1.7674
44					0.8607	0.9921	1.1204	1.2457	1.3680	1.4876	1.6045	1.7187	1.8304	1.9397
46					0.9407	1.0843	1.2246	1.3615	1.4952	1.6259	1.7537	1.8785	2.0006	2.1201
48					1.0243	1.1807	1.3334	1.4824	1.6281	1.7704	1.9095	2.0454	2.1784	2.3084
50					1.1114	1.2811	1.4468	1.6086	1.7666	1.9210	2.0719	2.2194	2.3637	2.5048
52					1.2021	1.3857	1.5648	1.7398	1.9107	2.0777	2.2410	2.4005	2.5566	2.7092
54					1.2964	1.4943	1.6875	1.8762	2.0605	2.2406	2.4167	2.5887	2.7570	2.9216
56					1.3942	1.6070	1.8148	2.0178	2.2160	2.4097	2.5990	2.7841	2.9650	3.1420
58					1.4956	1.7239	1.9468	2.1645	2.3771	2.5849	2.7879	2.9865	3.1806	3.3705
60					1.6005	1.8448	2.0834	2.3163	2.5439	2.7662	2.9835	3.1960	3.4037	3.6069
62							2.2246	2.4733	2.7163	2.9537	3.1857	3.4126	3.6344	3.8514
64									2.8944	3.1473	3.3946	3.6363	3.8727	4.1039
66									3.0781	3.3471	3.6101	3.8671	4.1185	4.3644
68												4.1051	4.3719	4.6329
70												4.3501	4.6328	4.9094
72												4.6022	4.9014	5.1940
74												4.8614	5.1774	5.4865

Honer's (1967) Total cubic meter volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.151)^2 / (0.710 + (0.3048 \cdot 355.623/Height))$ +/- 17.3% Accuracy

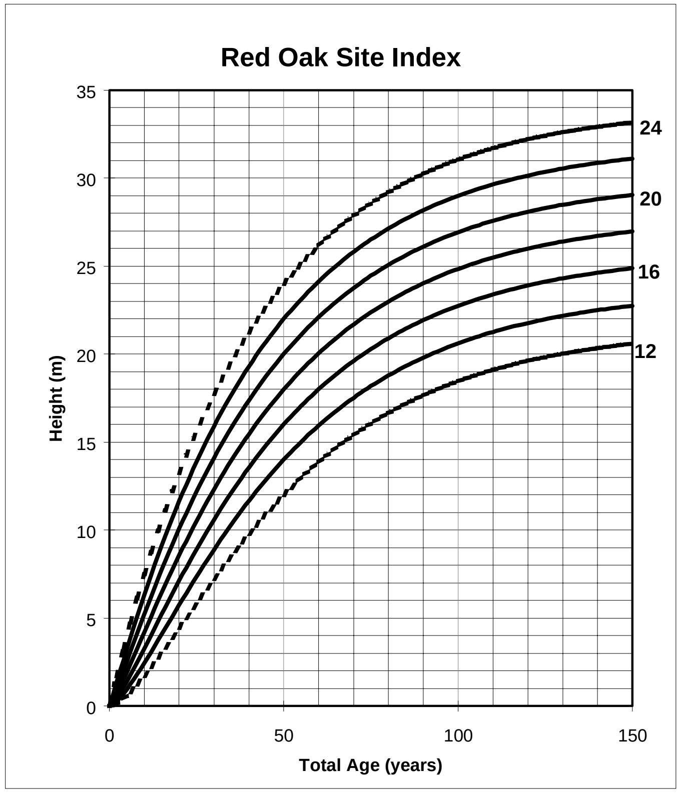
1333 Trees


Site index curves for natural stands
Red Pine : Natural Stands
Density Management Diagram
for Ontario (log/log scale)
D. J. Smith and M.E. Woods. 1997
Total height (m)
Breast-Height Age (years)
Site Index
23
21
19
17
15
13
40 cm
38 cm
36 cm
34 cm
32 cm
30 cm
28 cm
26 cm
24 cm
22 cm
20 cm
18 cm
16 cm
14 cm
12 cm
10 cm
8 cm
6 m
8 m
10 m
12 m
14 m
16 m
18 m
20 m
22 m
24 m
26 m
28 m
30 m
Quadratic
Mean
Diameter
Top
Height
Mean Total Tree Volume (m^3)
Density (sph)
100
500
1,000
5,000
10,000
20,000


Red Pine : Plantation
Density Management Diagram
for Ontario (log/log scale)
D. J. Smith and M.E. Woods. 1997
Site index curves for plantations
Total height (m)
Breast-Height Age (years)
Site Index
28
24
20
16
12
8
Mean Total Tree Volume (m³)
Density (sph)
Quadratic
Mean
Diameter
Top
Height
40 cm
38 cm
36 cm
34 cm
32 cm
30 cm
28 cm
26 cm
24 cm
22 cm
20 cm
18 cm
16 cm
14 cm
12 cm
10 cm
8 cm
30 m
28 m
26 m
24 m
22 m
20 m
18 m
16 m
14 m
12 m
10 m
8 m
6 m
2
1
0.5
0.1
0.05
0.01
100
500
1,000
5,000
10,000
20,000

Red Oak Growth & Yield Factsheet

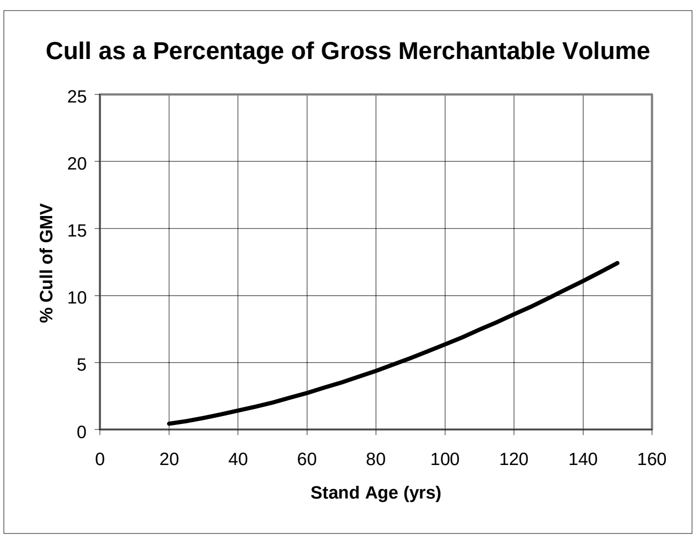
Age	Site Index 12	14	16	18	20	22	24
5	0.61	0.96	1.40	1.92	2.54	3.24	4.01
10	1.72	2.44	3.27	4.19	5.22	6.31	7.49
15	3.04	4.07	5.21	6.43	7.74	9.11	10.55
20	4.45	5.73	7.11	8.55	10.07	11.63	13.24
25	5.86	7.35	8.91	10.52	12.19	13.89	15.62
30	7.24	8.89	10.59	12.32	14.10	15.90	17.73
35	8.55	10.33	12.14	13.97	15.83	17.70	19.59
40	9.79	11.66	13.55	15.45	17.38	19.30	21.24
45	10.94	12.88	14.84	16.79	18.76	20.73	22.70
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00
55	12.97	15.02	17.05	19.08	21.11	23.13	25.14
60	13.86	15.93	18.00	20.04	22.09	24.13	26.16
65	14.66	16.76	18.85	20.91	22.97	25.02	27.06
70	15.39	17.51	19.61	21.68	23.75	25.81	27.85
75	16.05	18.18	20.29	22.37	24.45	26.51	28.56
80	16.64	18.78	20.90	22.99	25.07	27.13	29.19
85	17.17	19.32	21.44	23.53	25.62	27.68	29.74
90	17.64	19.80	21.93	24.02	26.11	28.17	30.23
95	18.07	20.23	22.36	24.45	26.54	28.61	30.67
100	18.45	20.61	22.74	24.84	26.93	28.99	31.05
105	18.79	20.95	23.08	25.18	27.27	29.34	31.39
110	19.10	21.26	23.39	25.49	27.57	29.64	31.70
115	19.37	21.53	23.66	25.76	27.84	29.91	31.96
120	19.61	21.77	23.90	26.00	28.08	30.15	32.20
125	19.82	21.98	24.11	26.21	28.30	30.36	32.41
130	20.02	22.18	24.30	26.40	28.48	30.55	32.60
135	20.19	22.35	24.47	26.57	28.65	30.71	32.77
140	20.34	22.50	24.62	26.72	28.80	30.86	32.91
145	20.47	22.63	24.76	26.85	28.93	30.99	33.04
150	20.59	22.75	24.87	26.97	29.05	31.11	33.16



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.1785	0.6619	-0.0241	25.0185	-0.7400	0.99	1.32	4.9
SI	0.1692	1.2648	-0.0110	-3.4334	-0.3557	0.97	2.09	7.8

Data Source: Carmean 1978. Northern Wisconsin and Upper Michigan. 37 plots with 136 dominant and Codominant trees.
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***

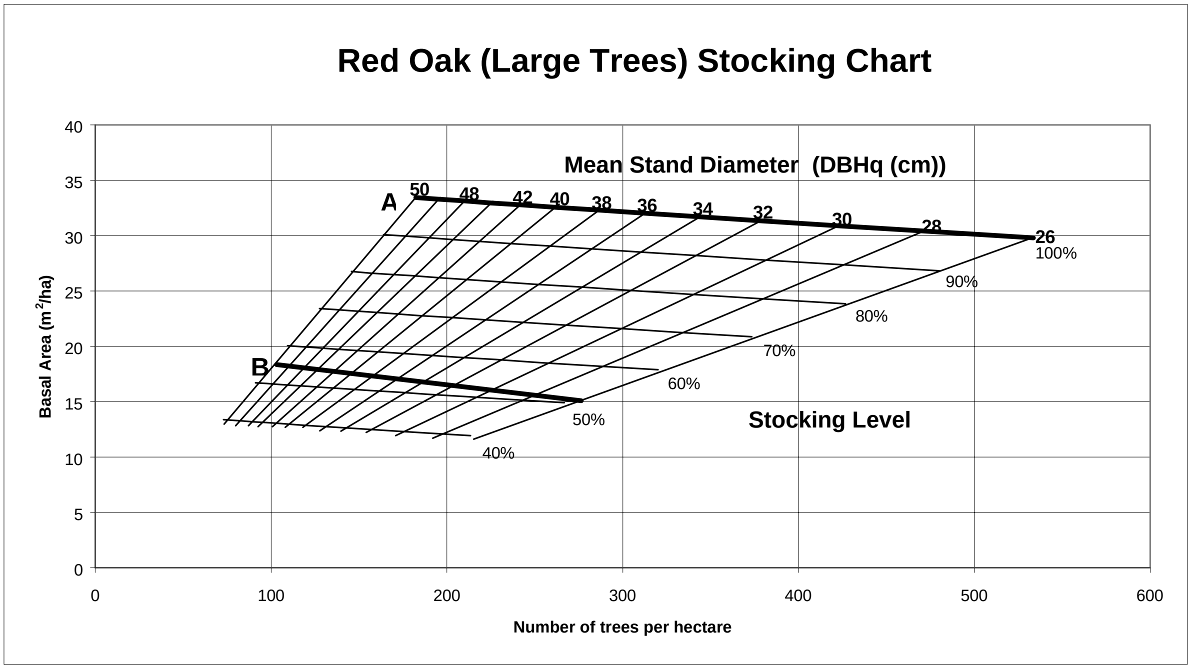


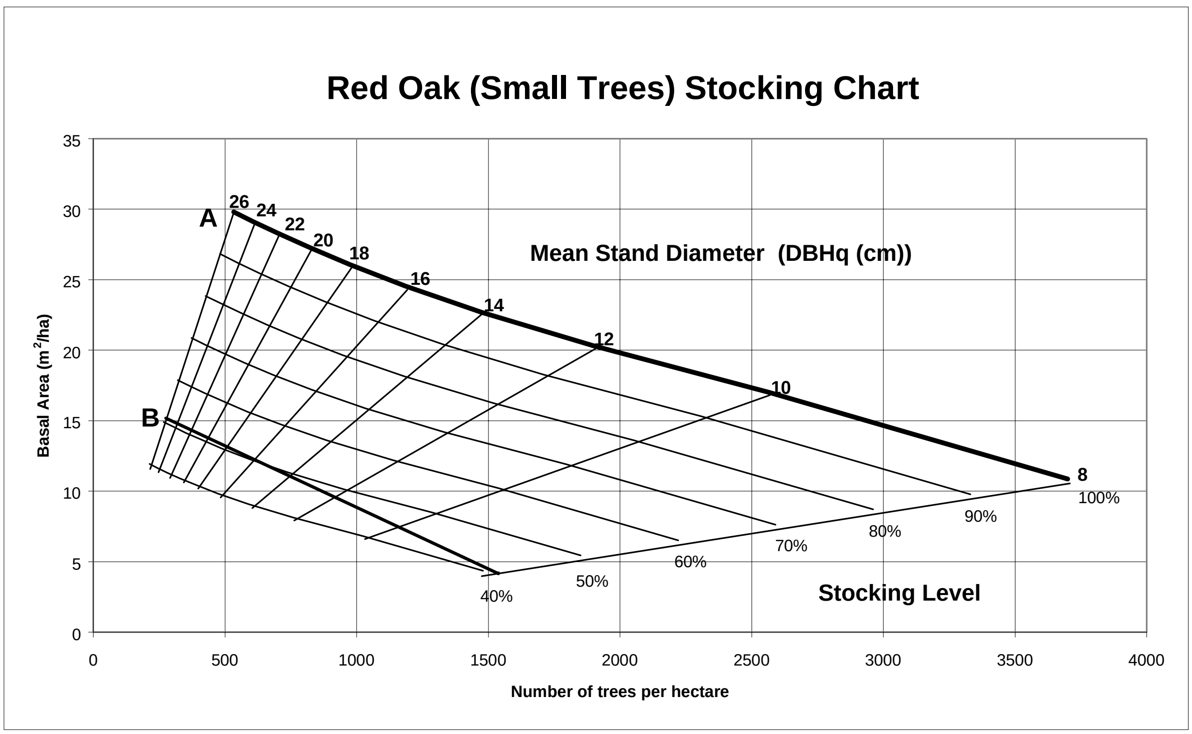
Cull $= 0.0031*Age^{1.6557}$

Data Source: Discussion by Basham, J.T. 1991. 42 Trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%	Age	%
20	0.44	105	6.88	190	18.38
25	0.64	110	7.44	195	19.19
30	0.87	115	8.00	200	20.01
35	1.12	120	8.59	205	20.84
40	1.39	125	9.19	210	21.69
45	1.69	130	9.80	215	22.55
50	2.02	135	10.44	220	23.43
55	2.36	140	11.08	225	24.31
60	2.73	145	11.75	230	25.22
65	3.11	150	12.43	235	26.13
70	3.52	155	13.12	240	27.06
75	3.94	160	13.83	245	28.00
80	4.39	165	14.55	250	28.95
85	4.85	170	15.29	255	29.91
90	5.33	175	16.04	260	30.89
95	5.83	180	16.80	265	31.88
100	6.35	185	17.58	270	32.88





(from McGill *et al.* 1991)

Red Oak Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0160	0.0233	0.0302	0.0368	0.0431	0.0490	0.0547	0.0601	0.0653	0.0702	0.0749	0.0794	0.0837	0.0879
12	0.0230	0.0335	0.0435	0.0530	0.0620	0.0706	0.0788	0.0866	0.0940	0.1011	0.1079	0.1144	0.1206	0.1266
14	0.0313	0.0457	0.0593	0.0722	0.0844	0.0961	0.1072	0.1178	0.1279	0.1376	0.1468	0.1557	0.1641	0.1723
16	0.0409	0.0596	0.0774	0.0943	0.1103	0.1255	0.1400	0.1539	0.1671	0.1797	0.1918	0.2033	0.2144	0.2250
18	0.0517	0.0755	0.0980	0.1193	0.1396	0.1589	0.1772	0.1947	0.2115	0.2274	0.2427	0.2573	0.2713	0.2848
20		0.0932	0.1209	0.1473	0.1723	0.1961	0.2188	0.2404	0.2611	0.2808	0.2996	0.3177	0.3350	0.3516
22		0.1127	0.1463	0.1782	0.2085	0.2373	0.2648	0.2909	0.3159	0.3397	0.3625	0.3844	0.4053	0.4254
24			0.1742	0.2121	0.2481	0.2824	0.3151	0.3462	0.3759	0.4043	0.4314	0.4574	0.4823	0.5062
26			0.2044	0.2489	0.2912	0.3315	0.3698	0.4063	0.4412	0.4745	0.5064	0.5369	0.5661	0.5941
28				0.2887	0.3378	0.3844	0.4289	0.4712	0.5117	0.5503	0.5873	0.6226	0.6565	0.6890
30				0.3314	0.3877	0.4413	0.4923	0.5409	0.5874	0.6317	0.6741	0.7148	0.7537	0.7910
32				0.3771	0.4412	0.5021	0.5601	0.6155	0.6683	0.7188	0.7670	0.8132	0.8575	0.9000
34				0.4257	0.4980	0.5668	0.6323	0.6948	0.7544	0.8114	0.8659	0.9181	0.9680	1.0160
36				0.4772	0.5583	0.6355	0.7089	0.7790	0.8458	0.9097	0.9708	1.0292	1.0853	1.1390
38				0.5317	0.6221	0.7080	0.7899	0.8679	0.9424	1.0136	1.0816	1.1468	1.2092	1.2691
40					0.6893	0.7845	0.8752	0.9617	1.0442	1.1231	1.1985	1.2707	1.3399	1.4062
42					0.7600	0.8650	0.9649	1.0603	1.1512	1.2382	1.3213	1.4009	1.4772	1.5504
44					0.8341	0.9493	1.0590	1.1636	1.2635	1.3589	1.4501	1.5375	1.6212	1.7015
46						1.0375	1.1575	1.2718	1.3810	1.4852	1.5850	1.6805	1.7720	1.8597
48							1.2603	1.3848	1.5037	1.6172	1.7258	1.8298	1.9294	2.0249
50							1.3675	1.5026	1.6316	1.7548	1.8726	1.9854	2.0935	2.1972
52							1.4791	1.6252	1.7647	1.8980	2.0254	2.1474	2.2644	2.3765
54								1.7527	1.9031	2.0468	2.1842	2.3158	2.4419	2.5628
56								1.8849	2.0466	2.2012	2.3490	2.4905	2.6261	2.7562
58									2.1954	2.3612	2.5198	2.6716	2.8170	2.9566
60									2.3495	2.5269	2.6966	2.8590	3.0147	3.1640
62									2.5087	2.6981	2.8793	3.0528	3.2190	3.3784
64									2.6732	2.8750	3.0681	3.2529	3.4300	3.5999
66									2.8429	3.0575	3.2628	3.4594	3.6478	3.8284
68									3.0178	3.2456	3.4636	3.6722	3.8722	4.0640
70										3.4394	3.6703	3.8914	4.1033	4.3065
72											3.8830	4.1170	4.3411	4.5561
74											4.1018	4.3489	4.5857	4.8128

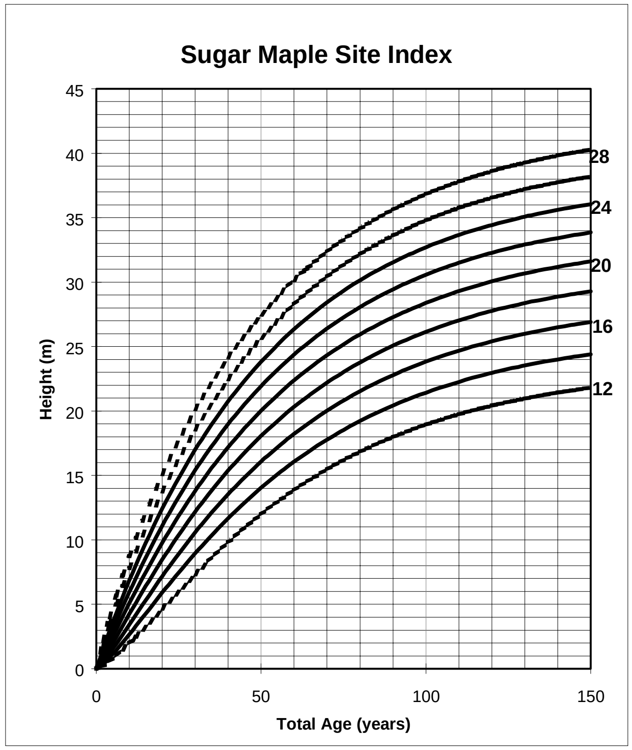
Honer's (1983) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.145)^2 / (1.512+(0.3048*336.509/Height))$ +/- 13.8 % Accuracy

——— Denotes range of data 40 Trees

Sugar Maple Growth & Yield Factsheet

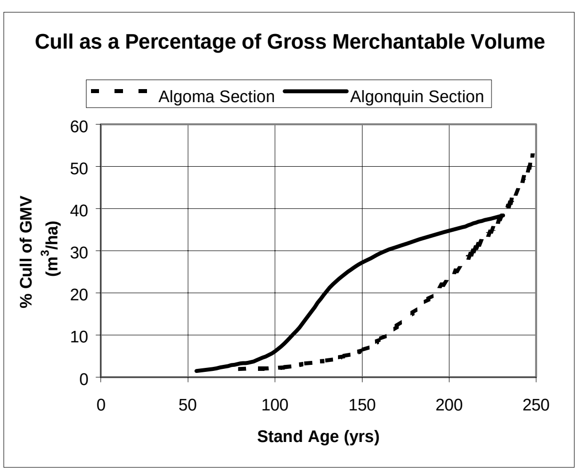
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.78	1.14	1.55	2.01	2.51	3.04	3.61	4.21	4.84
10	1.97	2.67	3.42	4.23	5.07	5.95	6.85	7.78	8.73
15	3.30	4.29	5.32	6.40	7.50	8.63	9.78	10.94	12.11
20	4.67	5.90	7.17	8.46	9.77	11.09	12.42	13.76	15.09
25	6.02	7.46	8.92	10.39	11.87	13.34	14.82	16.29	17.76
30	7.34	8.95	10.57	12.18	13.79	15.40	16.99	18.57	20.14
35	8.60	10.36	12.11	13.84	15.56	17.27	18.95	20.62	22.28
40	9.79	11.68	13.54	15.37	17.18	18.97	20.74	22.48	24.20
45	10.92	12.90	14.86	16.78	18.67	20.52	22.35	24.15	25.93
50	11.97	14.04	16.07	18.07	20.02	21.93	23.82	25.67	27.49
55	12.94	15.10	17.19	19.24	21.25	23.22	25.14	27.04	28.90
60	13.85	16.07	18.22	20.32	22.37	24.38	26.35	28.28	30.17
65	14.69	16.96	19.16	21.31	23.40	25.44	27.44	29.40	31.32
70	15.46	17.78	20.02	22.21	24.33	26.40	28.43	30.41	32.36
75	16.17	18.53	20.81	23.03	25.18	27.28	29.33	31.33	33.30
80	16.82	19.22	21.53	23.77	25.95	28.07	30.14	32.16	34.15
85	17.42	19.85	22.19	24.45	26.65	28.79	30.88	32.92	34.92
90	17.97	20.43	22.79	25.07	27.29	29.44	31.55	33.60	35.61
95	18.48	20.95	23.33	25.63	27.87	30.04	32.15	34.22	36.25
100	18.93	21.43	23.83	26.15	28.39	30.58	32.71	34.78	36.82
105	19.35	21.87	24.28	26.61	28.87	31.07	33.20	35.29	37.33
110	19.74	22.27	24.69	27.04	29.31	31.51	33.66	35.75	37.80
115	20.09	22.63	25.07	27.42	29.70	31.91	34.07	36.17	38.23
120	20.41	22.96	25.41	27.77	30.06	32.28	34.44	36.55	38.61
125	20.70	23.26	25.72	28.09	30.38	32.61	34.78	36.89	38.96
130	20.96	23.53	26.00	28.38	30.68	32.91	35.09	37.21	39.28
135	21.20	23.78	26.26	28.64	30.95	33.18	35.36	37.49	39.56
140	21.42	24.01	26.49	28.88	31.19	33.43	35.62	37.74	39.82
145	21.62	24.21	26.70	29.09	31.41	33.66	35.84	37.98	40.06
150	21.80	24.40	26.89	29.29	31.61	33.86	36.05	38.19	40.27

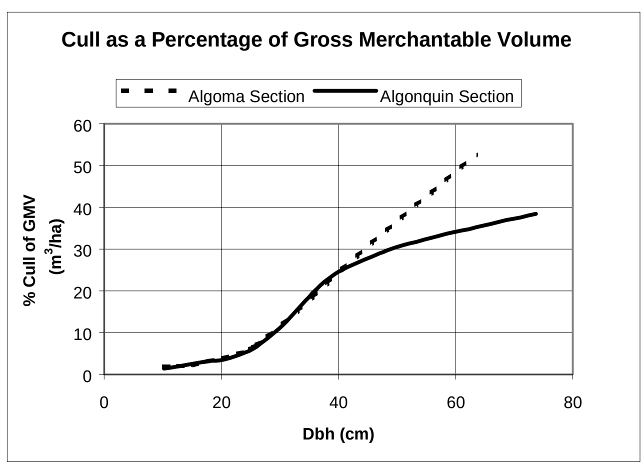


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$

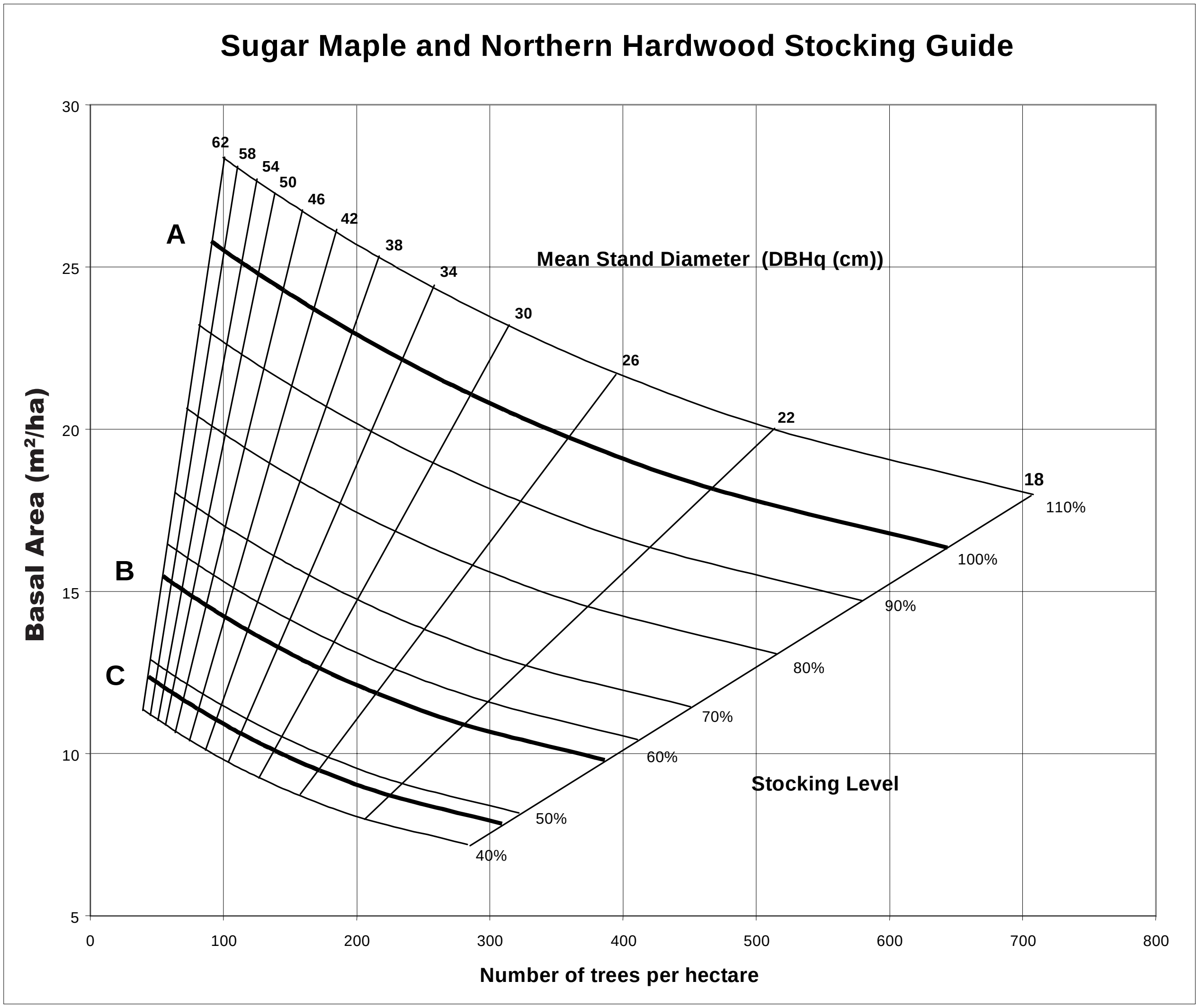
	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.1308	0.6904	-0.0195	10.1563	-0.5330	0.99	0.38	1.6
SI	0.1984	1.2089	-0.0110	-2.4917	-0.2542	0.98	0.58	2.0

Data Source: *Carmean 1978.* *Northwest Wisconsin and Upper Michigan.* *177 plots having 721 dominant and codominant trees.*
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***





Data Source:Morawski, Z.J.R. 1978 3922 Trees



(from Tubbs 1977*b*)

	110%		A line		90%		80%		70%		B line		50%		C line	
DBHq (cm)	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**	**Trees # ha**	**BA m^2/ha**
18	708	17.99	644	16.35	579	14.72	515	13.08	451	11.45	411	10.43	322	8.18	309	7.85
22	515	19.97	468	18.16	421	16.34	375	14.53	328	12.71	299	11.58	234	9.08	225	8.72
26	395	21.73	359	19.75	323	17.78	287	15.80	252	13.83	229	12.60	180	9.88	172	9.48
30	315	23.18	286	21.07	258	18.96	229	16.85	201	14.75	183	13.44	143	10.53	137	10.11
34	258	24.35	235	22.14	211	19.92	188	17.71	164	15.50	150	14.12	117	11.07	113	10.63
38	217	25.30	197	23.00	177	20.70	158	18.40	138	16.10	126	14.67	98	11.50	95	11.04
42	185	26.07	168	23.70	151	21.33	134	18.96	118	16.59	107	15.12	84	11.85	81	11.38
46	160	26.71	145	24.28	131	21.85	116	19.43	102	17.00	93	15.49	73	12.14	70	11.66
50	140	27.24	127	24.76	115	22.29	102	19.81	89	17.33	81	15.80	64	12.38	61	11.89
54	124	27.68	113	25.16	102	22.65	90	20.13	79	17.62	72	16.06	56	12.58	54	12.08
58	111	28.06	101	25.51	91	22.96	81	20.40	71	17.85	64	16.27	50	12.75	48	12.24
62	100	28.38	91	25.80	82	23.22	73	20.64	63	18.06	58	16.46	45	12.90	44	12.38

Sugar Maple Standard Volume Table (m^3)

Dbh	Total Tree Height (m)													
(cm)	4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0143	0.0211	0.0276	0.0340	0.0401	0.0461	0.0518	0.0574	0.0628	0.0681	0.0732	0.0781	0.0829	0.0876
12	0.0206	0.0304	0.0398	0.0489	0.0578	0.0663	0.0746	0.0827	0.0905	0.0980	0.1054	0.1125	0.1194	0.1261
14	0.0280	0.0413	0.0542	0.0666	0.0787	0.0903	0.1016	0.1125	0.1231	0.1334	0.1434	0.1531	0.1625	0.1717
16	0.0366	0.0540	0.0708	0.0870	0.1027	0.1180	0.1327	0.1470	0.1608	0.1743	0.1873	0.2000	0.2123	0.2243
18	0.0463	0.0683	0.0896	0.1101	0.1300	0.1493	0.1679	0.1860	0.2036	0.2206	0.2371	0.2531	0.2687	0.2838
20	0.0572	0.0843	0.1106	0.1360	0.1605	0.1843	0.2073	0.2297	0.2513	0.2723	0.2927	0.3125	0.3317	0.3504
22	0.0692	0.1021	0.1338	0.1645	0.1942	0.2230	0.2509	0.2779	0.3041	0.3295	0.3542	0.3781	0.4014	0.4240
24	0.0824	0.1215	0.1592	0.1958	0.2312	0.2654	0.2986	0.3307	0.3619	0.3921	0.4215	0.4500	0.4777	0.5046
26	0.0967	0.1425	0.1869	0.2298	0.2713	0.3115	0.3504	0.3881	0.4247	0.4602	0.4947	0.5281	0.5606	0.5922
28	0.1121	0.1653	0.2168	0.2665	0.3146	0.3612	0.4064	0.4501	0.4926	0.5337	0.5737	0.6125	0.6502	0.6868
30	0.1287	0.1898	0.2488	0.3059	0.3612	0.4147	0.4665	0.5167	0.5655	0.6127	0.6586	0.7031	0.7464	0.7884
32	0.1464	0.2159	0.2831	0.3481	0.4109	0.4718	0.5308	0.5879	0.6434	0.6971	0.7493	0.8000	0.8492	0.8970
34		0.2438	0.3196	0.3929	0.4639	0.5326	0.5992	0.6637	0.7263	0.7870	0.8459	0.9031	0.9587	1.0127
36			0.3583	0.4405	0.5201	0.5971	0.6718	0.7441	0.8143	0.8823	0.9483	1.0125	1.0748	1.1353
38				0.4908	0.5795	0.6653	0.7485	0.8291	0.9072	0.9831	1.0566	1.1281	1.1975	1.2649
40				0.5439	0.6421	0.7372	0.8294	0.9187	1.0052	1.0893	1.1708	1.2500	1.3269	1.4016
42				0.5996	0.7079	0.8128	0.9144	1.0128	1.1083	1.2009	1.2908	1.3781	1.4629	1.5453
44					0.7769	0.8920	1.0035	1.1116	1.2164	1.3180	1.4167	1.5125	1.6055	1.6959
46					0.8492	0.9750	1.0968	1.2149	1.3294	1.4405	1.5484	1.6531	1.7548	1.8536
48					0.9246	1.0616	1.1943	1.3229	1.4476	1.5685	1.6859	1.7999	1.9107	2.0183
50						1.1519	1.2959	1.4354	1.5707	1.7020	1.8294	1.9531	2.0732	2.1900
52						1.2459	1.4016	1.5525	1.6989	1.8408	1.9786	2.1124	2.2424	2.3687
54						1.3436	1.5115	1.6743	1.8321	1.9852	2.1338	2.2781	2.4182	2.5544
56							1.6255	1.8006	1.9703	2.1349	2.2948	2.4499	2.6007	2.7471
58							1.7437	1.9315	2.1135	2.2902	2.4616	2.6280	2.7897	2.9469
60							1.8660	2.0670	2.2618	2.4508	2.6343	2.8124	2.9854	3.1536
62							1.9925	2.2071	2.4151	2.6169	2.8128	3.0030	3.1878	3.3674
64								2.3518	2.5734	2.7885	2.9972	3.1999	3.3968	3.5881
66								2.5010	2.7368	2.9655	3.1875	3.4030	3.6124	3.8159
68									2.9052	3.1480	3.3836	3.6124	3.8346	4.0506
70										3.3358	3.5855	3.8280	4.0635	4.2924
72										3.5292	3.7934	4.0499	4.2990	4.5412
74										3.7280	4.0070	4.2780	4.5412	4.7970

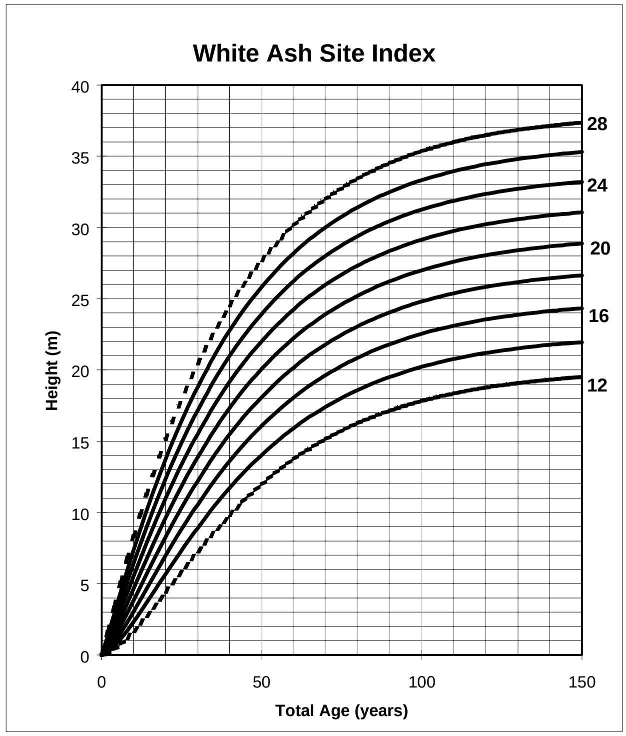
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.145)^2 / (1.046+(0.3048 \cdot 383.972/Height))$ +/- 30.3% Accuracy

——— Denotes range of data 3967 Trees

White Ash Growth & Yield Factsheet

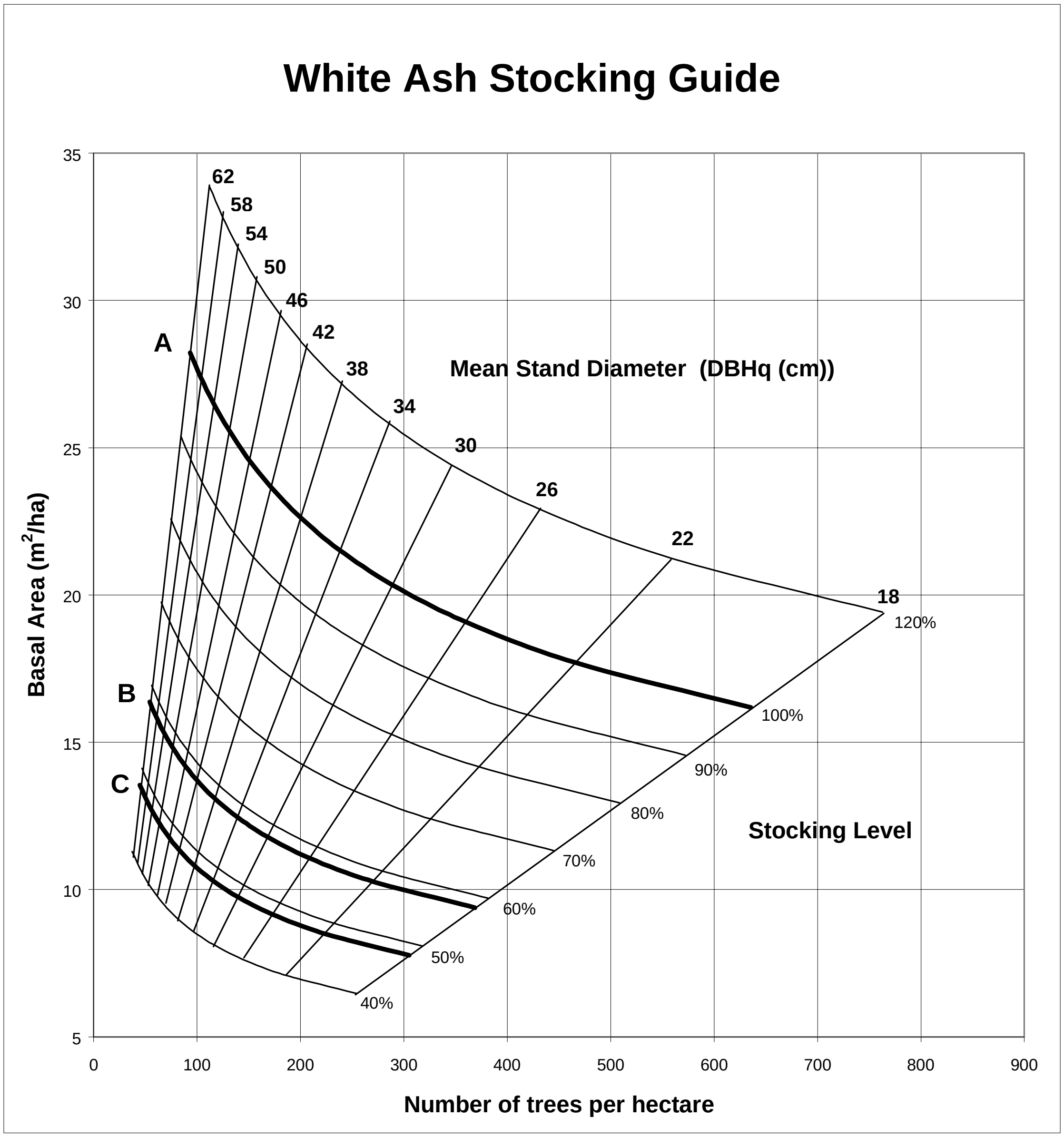
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.57	0.87	1.22	1.63	2.09	2.59	3.13	3.70	4.31
10	1.68	2.33	3.05	3.83	4.66	5.53	6.44	7.37	8.33
15	3.02	3.99	5.02	6.10	7.22	8.36	9.54	10.73	11.94
20	4.45	5.69	6.97	8.29	9.63	10.99	12.36	13.75	15.14
25	5.88	7.34	8.83	10.34	11.85	13.38	14.91	16.43	17.96
30	7.28	8.91	10.57	12.22	13.88	15.53	17.18	18.81	20.45
35	8.59	10.38	12.16	13.94	15.70	17.45	19.19	20.92	22.63
40	9.81	11.72	13.61	15.48	17.33	19.17	20.98	22.77	24.55
45	10.94	12.94	14.92	16.87	18.79	20.69	22.56	24.41	26.23
50	11.96	14.05	16.09	18.10	20.08	22.03	23.95	25.84	27.71
55	12.89	15.04	17.14	19.20	21.23	23.22	25.17	27.10	29.00
60	13.72	15.92	18.07	20.18	22.24	24.26	26.25	28.21	30.13
65	14.47	16.72	18.90	21.04	23.13	25.18	27.20	29.18	31.13
70	15.14	17.42	19.64	21.80	23.92	25.99	28.03	30.03	31.99
75	15.73	18.04	20.29	22.47	24.61	26.70	28.76	30.77	32.75
80	16.25	18.59	20.86	23.07	25.22	27.33	29.40	31.43	33.42
85	16.72	19.08	21.36	23.59	25.76	27.88	29.96	32.00	34.00
90	17.13	19.51	21.81	24.04	26.23	28.36	30.45	32.50	34.51
95	17.49	19.88	22.20	24.45	26.64	28.78	30.88	32.93	34.96
100	17.81	20.22	22.54	24.80	27.00	29.15	31.25	33.32	35.34
105	18.10	20.51	22.84	25.11	27.32	29.47	31.58	33.65	35.69
110	18.34	20.77	23.11	25.38	27.59	29.76	31.87	33.95	35.98
115	18.56	20.99	23.34	25.62	27.84	30.00	32.12	34.20	36.24
120	18.75	21.19	23.54	25.83	28.05	30.22	32.35	34.43	36.47
125	18.92	21.36	23.72	26.01	28.24	30.41	32.54	34.62	36.67
130	19.07	21.51	23.88	26.17	28.40	30.58	32.71	34.80	36.85
135	19.20	21.65	24.01	26.31	28.54	30.72	32.86	34.95	37.00
140	19.31	21.76	24.13	26.43	28.67	30.85	32.98	35.08	37.13
145	19.41	21.87	24.24	26.54	28.78	30.96	33.10	35.19	37.25
150	19.50	21.95	24.33	26.63	28.87	31.06	33.20	35.29	37.35



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	4.1492	0.7531	-0.0269	14.5384	-0.5811	0.99	0.42	1.6
SI	0.1728	1.2560	-0.0110	-3.3605	-0.3452	0.99	0.61	2.9

Data Source: *Carmean 1978.* *Northern Wisconsin and Upper Michigan.* *73 plots having 275 dominant and Codominant trees.*
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***

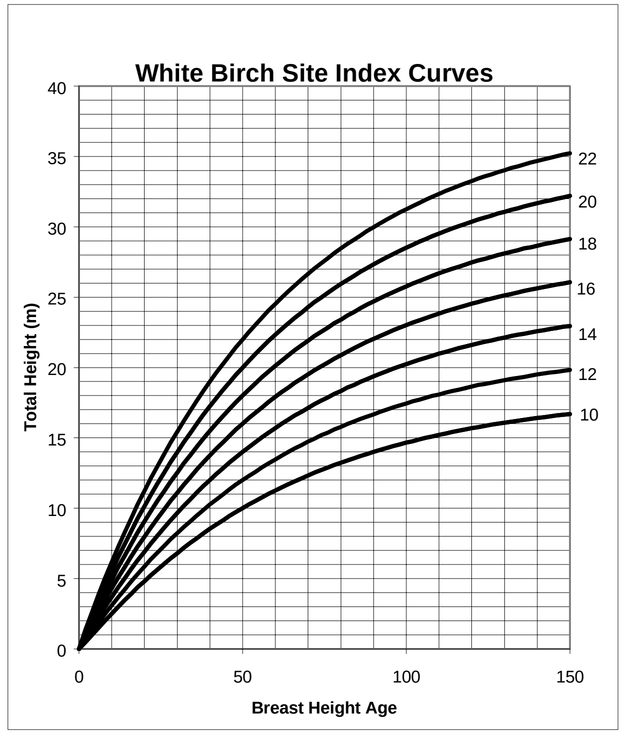


(from Crow and Erdman)

DBHq	120%		A Line		90%		80%		70%		B Line		50%		C Line	
(cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	763	19.4	636	16.2	572	14.6	509	12.9	445	11.3	381	9.7	318	8.1	305	7.8
22	559	21.2	466	17.7	419	15.9	373	14.2	326	12.4	279	10.6	233	8.9	224	8.5
26	431	22.9	360	19.1	324	17.2	288	15.3	252	13.4	216	11.5	180	9.5	173	9.2
30	346	24.4	288	20.4	259	18.3	230	16.3	202	14.3	173	12.2	144	10.2	138	9.8
34	285	25.8	237	21.5	213	19.4	190	17.2	166	15.1	142	12.9	119	10.8	114	10.3
38	240	27.2	200	22.6	180	20.4	160	18.1	140	15.9	120	13.6	100	11.3	96	10.9
42	205	28.4	171	23.7	154	21.3	137	18.9	120	16.6	103	14.2	85	11.8	82	11.4
46	178	29.6	148	24.7	134	22.2	119	19.7	104	17.3	89	14.8	74	12.3	71	11.8
50	157	30.7	130	25.6	117	23.1	104	20.5	91	17.9	78	15.4	65	12.8	63	12.3
54	139	31.8	116	26.5	104	23.9	93	21.2	81	18.6	69	15.9	58	13.3	56	12.7
58	124	32.9	104	27.4	93	24.6	83	21.9	73	19.2	62	16.4	52	13.7	50	13.1
62	112	33.9	93	28.2	84	25.4	75	22.6	65	19.8	56	16.9	47	14.1	45	13.5

White Birch Growth & Yield Factsheet

Age	Site Index 10	12	14	16	18	20	22
5	1.3	1.6	1.9	2.2	2.6	2.9	3.2
10	2.5	3.1	3.7	4.3	4.9	5.5	6.2
15	3.7	4.5	5.4	6.2	7.1	7.9	8.8
20	4.8	5.8	6.9	8.0	9.0	10.1	11.2
25	5.8	7.1	8.3	9.6	10.9	12.1	13.4
30	6.8	8.2	9.7	11.1	12.5	14.0	15.4
35	7.7	9.3	10.9	12.5	14.1	15.7	17.3
40	8.5	10.3	12.0	13.8	15.5	17.2	19.0
45	9.3	11.2	13.0	14.9	16.8	18.7	20.6
50	10.0	12.0	14.0	16.0	18.0	20.0	22.0
55	10.7	12.8	14.9	17.0	19.1	21.2	23.3
60	11.3	13.5	15.7	17.9	20.1	22.3	24.5
65	11.8	14.1	16.4	18.7	21.0	23.3	25.6
70	12.3	14.7	17.1	19.5	21.9	24.3	26.7
75	12.8	15.3	17.8	20.2	22.7	25.1	27.6
80	13.2	15.8	18.3	20.9	23.4	25.9	28.5
85	13.6	16.3	18.9	21.5	24.1	26.7	29.2
90	14.0	16.7	19.4	22.0	24.7	27.3	30.0
95	14.3	17.1	19.8	22.5	25.3	28.0	30.6
100	14.7	17.4	20.2	23.0	25.8	28.5	31.3
105	14.9	17.8	20.6	23.4	26.3	29.0	31.8
110	15.2	18.1	21.0	23.8	26.7	29.5	32.3
115	15.5	18.4	21.3	24.2	27.1	30.0	32.8
120	15.7	18.6	21.6	24.5	27.5	30.4	33.3
125	15.9	18.9	21.9	24.8	27.8	30.7	33.7
130	16.1	19.1	22.1	25.1	28.1	31.1	34.0
135	16.2	19.3	22.4	25.4	28.4	31.4	34.4
140	16.4	19.5	22.6	25.6	28.7	31.7	34.7
145	16.6	19.7	22.8	25.8	28.9	31.9	35.0
150	16.7	19.8	23.0	26.0	29.1	32.2	35.2

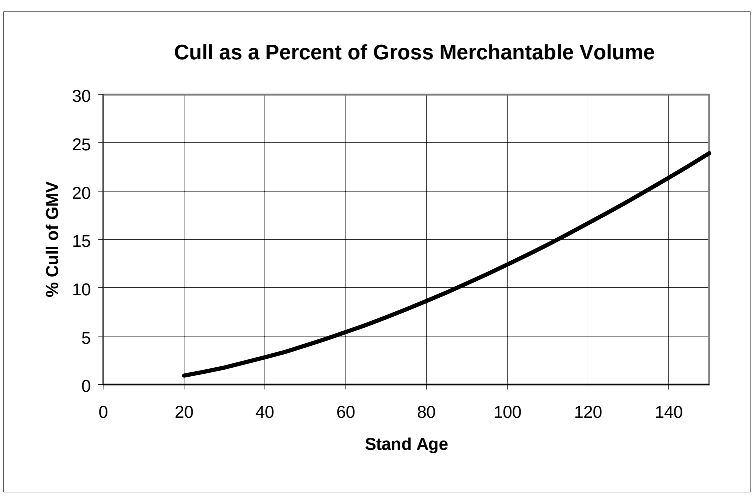


$Ht=[b_1*(SI*.3048^{b_2})*(1-EXP^{b_3*Age})^{b_4*(SI*.3048^{b_5})}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	2.4321	0.9207	-0.0168	1.5297	-0.1042	0.99	0.49	0.4
SI	0.5119	1.0229	-0.0167	-1.0284	-0.0049	0.99	0.33	1.3

Data Source: Carmean 1978

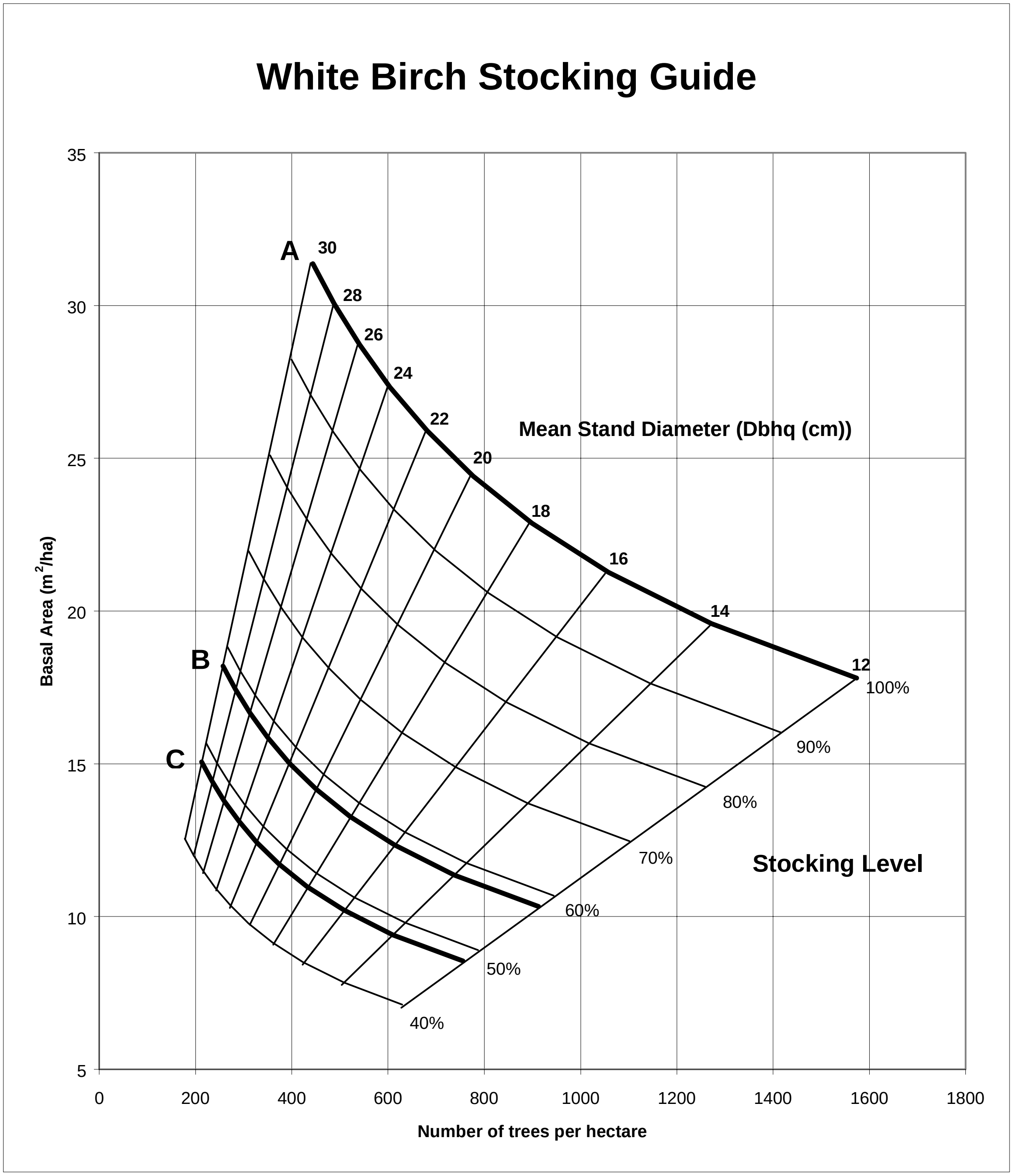
Lake States Data. Number of trees used for equation derivation unknown.
Add 4 Years to breast-height age to get total age.



Cull = 0.007 * Stand Age$^{1.624}$

Data Source: Basham, J.T. 1991. 936 trees from the Boreal forest

Cull as a % of Gross Merchantable Volume					
Age	%	Age	%	Age	%
20	0.91	54	4.56	88	5.70
22	1.06	56	4.83	90	5.97
24	1.22	58	5.12	95	6.71
26	1.39	60	5.41	100	7.50
28	1.57	62	5.70	105	8.36
30	1.75	64	6.00	110	9.27
32	1.95	66	6.31	115	10.25
34	2.15	68	6.62	120	11.29
36	2.36	70	6.94	125	12.38
38	2.57	72	7.27	130	13.54
40	2.80	74	7.60	135	14.75
42	3.03	76	7.93	140	16.03
44	3.27	78	8.28	145	17.36
46	3.51	80	8.62	150	18.76
48	3.76	82	8.98		
50	4.02	84	9.34		
52	4.28	86	9.70		



(from Marquis et al., 1989)

	A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
12	1574	17.8	1417	16.0	1259	14.2	1102	12.5	913	10.3	787	8.9	755	8.5
14	1272	19.6	1145	17.6	1018	15.7	890	13.7	738	11.4	636	9.8	611	9.4
16	1058	21.3	952	19.1	846	17.0	740	14.9	613	12.3	529	10.6	508	10.2
18	899	22.9	809	20.6	719	18.3	629	16.0	521	13.3	449	11.4	431	11.0
20	777	24.4	699	22.0	622	19.5	544	17.1	451	14.2	389	12.2	373	11.7
22	681	25.9	613	23.3	545	20.7	477	18.1	395	15.0	341	12.9	327	12.4
24	604	27.3	544	24.6	483	21.9	423	19.1	350	15.9	302	13.7	290	13.1
26	541	28.7	487	25.8	433	23.0	379	20.1	314	16.7	270	14.4	260	13.8
28	488	30.1	439	27.1	391	24.0	342	21.0	283	17.4	244	15.0	234	14.4
30	444	31.4	399	28.2	355	25.1	311	22.0	257	18.2	222	15.7	213	15.1

White Birch Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m)													
	4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0172	0.0247	0.0316	0.0380	0.0439	0.0493	0.0544	0.0591	0.0636	0.0677	0.0716	0.0753	0.0787	0.0820
12	0.0248	0.0356	0.0455	0.0547	0.0632	0.0710	0.0783	0.0852	0.0915	0.0975	0.1031	0.1084	0.1133	0.1180
14	0.0337	0.0485	0.0620	0.0745	0.0860	0.0967	0.1066	0.1159	0.1246	0.1327	0.1403	0.1475	0.1542	0.1606
16	0.0441	0.0633	0.0810	0.0972	0.1123	0.1263	0.1393	0.1514	0.1627	0.1733	0.1833	0.1926	0.2015	0.2098
18	0.0558	0.0801	0.1025	0.1231	0.1421	0.1598	0.1763	0.1916	0.2059	0.2194	0.2320	0.2438	0.2550	0.2655
20		0.0989	0.1265	0.1519	0.1755	0.1973	0.2176	0.2365	0.2542	0.2708	0.2864	0.3010	0.3148	0.3278
22		0.1197	0.1531	0.1839	0.2123	0.2387	0.2633	0.2862	0.3076	0.3277	0.3465	0.3642	0.3809	0.3966
24			0.1822	0.2188	0.2527	0.2841	0.3134	0.3406	0.3661	0.3900	0.4124	0.4334	0.4533	0.4720
26			0.2138	0.2568	0.2966	0.3335	0.3678	0.3998	0.4297	0.4577	0.4840	0.5087	0.5320	0.5540
28				0.2978	0.3439	0.3867	0.4265	0.4636	0.4983	0.5308	0.5613	0.5900	0.6170	0.6425
30				0.3419	0.3948	0.4440	0.4896	0.5322	0.5720	0.6093	0.6443	0.6773	0.7083	0.7376
32				0.3890	0.4492	0.5051	0.5571	0.6056	0.6509	0.6933	0.7331	0.7706	0.8059	0.8392
34				0.4391	0.5071	0.5702	0.6289	0.6836	0.7348	0.7827	0.8276	0.8699	0.9097	0.9474
36				0.4923	0.5686	0.6393	0.7051	0.7664	0.8237	0.8774	0.9279	0.9753	1.0199	1.0621
38				0.5485	0.6335	0.7123	0.7856	0.8539	0.9178	0.9776	1.0338	1.0866	1.1364	1.1834
40					0.7019	0.7893	0.8705	0.9462	1.0170	1.0833	1.1455	1.2040	1.2592	1.3112
42					0.7739	0.8702	0.9597	1.0432	1.1212	1.1943	1.2629	1.3274	1.3882	1.4456
44					0.8493	0.9550	1.0533	1.1449	1.2305	1.3108	1.3861	1.4569	1.5236	1.5866
46						1.0438	1.1512	1.2513	1.3449	1.4326	1.5149	1.5923	1.6653	1.7341
48							1.2535	1.3625	1.4644	1.5599	1.6495	1.7338	1.8132	1.8882
50							1.3601	1.4784	1.5890	1.6926	1.7898	1.8813	1.9675	2.0488
52							1.4711	1.5991	1.7187	1.8307	1.9359	2.0348	2.1280	2.2160
54								1.7244	1.8534	1.9743	2.0877	2.1943	2.2948	2.3897
56								1.8545	1.9933	2.1232	2.2452	2.3599	2.4680	2.5700
58									2.1382	2.2776	2.4084	2.5315	2.6474	2.7568
60									2.2882	2.4374	2.5774	2.7091	2.8331	2.9502
62									2.4433	2.6026	2.7521	2.8927	3.0252	3.1502
64									2.6034	2.7732	2.9325	3.0823	3.2235	3.3567
66									2.7687	2.9492	3.1186	3.2780	3.4281	3.5698
68									2.9390	3.1306	3.3105	3.4796	3.6390	3.7894
70										3.3175	3.5081	3.6873	3.8562	4.0156
72											3.7114	3.9010	4.0797	4.2483
74											3.9205	4.1208	4.3095	4.4876

Honer's (1983) Total cubic metre volume equation

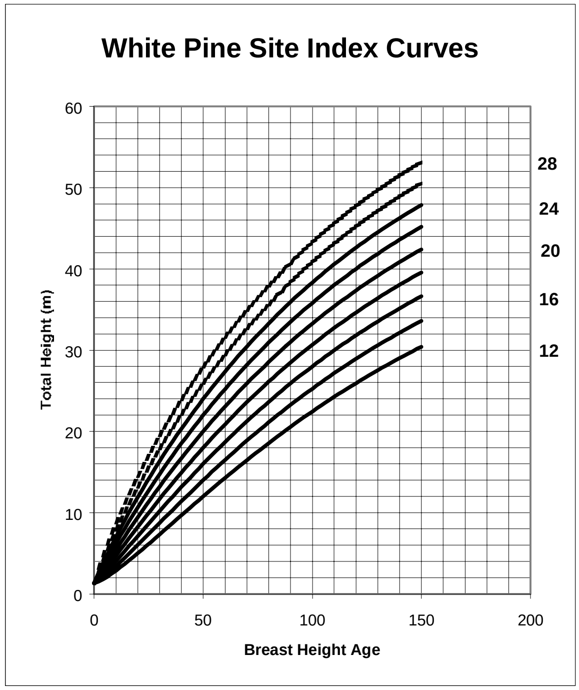
Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.176)^2 / (2.222+(0.3048 \cdot 300.373/Height))$

+/- 22.5 % Accuracy

1272 Trees

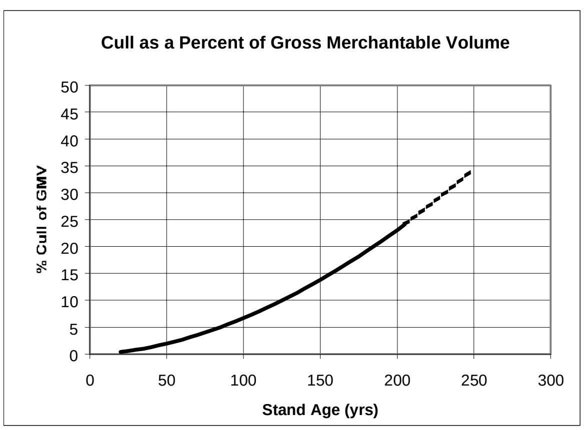
White Pine Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24	26	28
5	1.95	2.23	2.56	2.94	3.36	3.82	4.33	4.88	5.46
10	2.87	3.42	4.03	4.71	5.43	6.20	7.02	7.88	8.78
15	3.91	4.70	5.57	6.49	7.46	8.48	9.54	10.64	11.77
20	5.01	6.03	7.11	8.25	9.43	10.65	11.92	13.21	14.53
25	6.16	7.38	8.66	9.98	11.34	12.74	14.17	15.63	17.11
30	7.32	8.73	10.18	11.68	13.19	14.75	16.32	17.92	19.54
35	8.50	10.07	11.68	13.33	14.99	16.67	18.37	20.09	21.82
40	9.67	11.40	13.15	14.93	16.72	18.52	20.33	22.16	23.99
45	10.84	12.71	14.59	16.49	18.39	20.29	22.21	24.12	26.04
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00
55	13.14	15.26	17.36	19.47	21.55	23.64	25.72	27.79	29.86
60	14.27	16.49	18.69	20.89	23.06	25.21	27.36	29.50	31.63
65	15.38	17.70	19.99	22.26	24.50	26.73	28.94	31.14	33.32
70	16.46	18.87	21.24	23.59	25.90	28.19	30.46	32.70	34.93
75	17.52	20.02	22.46	24.88	27.24	29.59	31.91	34.20	36.48
80	18.56	21.13	23.64	26.12	28.54	30.93	33.30	35.64	37.95
85	19.57	22.21	24.79	27.32	29.79	32.23	34.64	37.01	39.36
90	20.56	23.26	25.89	28.47	30.99	33.47	35.92	38.33	40.71
95	21.52	24.28	26.97	29.59	32.15	34.67	37.15	39.59	
100	22.46	25.27	28.00	30.67	33.27	35.82	38.33	40.80	
105	23.37	26.23	29.01	31.71	34.34	36.93	39.47		
110	24.25	27.16	29.98	32.72	35.38	37.99	40.56		
115	25.11	28.06	30.91	33.69	36.38	39.02			
120	25.94	28.93	31.82	34.62	37.34	40.00			
125	26.75	29.78	32.69	35.52	38.27	40.95			
130	27.53	30.59	33.54	36.39	39.16				
135	28.29	31.38	34.35	37.23	40.02				
140	29.02	32.14	35.14	38.04	40.84				
145	29.73	32.88	35.90	38.82					
150	30.42	33.59	36.63	39.57					



$Ht=1.3+[b1*(SI^{b2})*(1-EXP^{b3*Age})^{b4*(SI^{-b5})}]$					R^2	SE	Maximum
	b_1	b_2	b_3	b_4	b_5		difference
Ht	14.4286	0.4764	-0.0081	2.8731	0.3428	0.99	0.99	4.7

Data Source: Central Ontario Based on 58 trees from FEC plots ***Total Age = Breast Height Age + 6 years***



Cull = 0.0018 * Stand Age$^{1.7852}$

Data Source: Basham, J.T. 1991. 1012 Trees

Cull as a % of Gross Merchantable Volume					
Age	%	Age	%	Age	%
20	0.38	105	7.30	190	21.05
25	0.56	110	7.94	195	22.05
30	0.78	115	8.59	200	23.07
35	1.03	120	9.27	205	24.11
40	1.30	125	9.97	210	25.17
45	1.61	130	10.69	215	26.25
50	1.94	135	11.44	220	27.35
55	2.30	140	12.21	225	28.47
60	2.69	145	12.99	230	29.61
65	3.10	150	13.80	235	30.77
70	3.54	155	14.64	240	31.95
75	4.01	160	15.49	245	33.14
80	4.49	165	16.37	250	34.36
85	5.01	170	17.26	255	35.60
90	5.55	175	18.18	260	36.85
95	6.11	180	19.12	265	38.13
100	6.69	185	20.07	270	39.42

White Pine Standard Volume Table (m^3/ha)

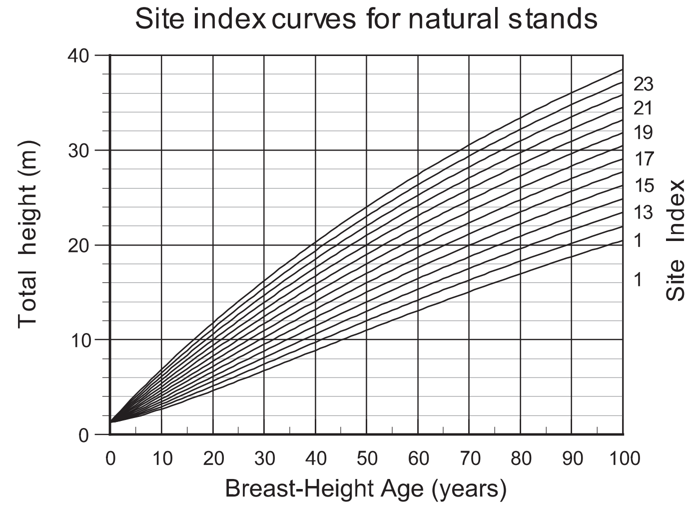
Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0152	0.0225	0.0297	0.0367	0.0435	0.0502	0.0567	0.0631						
12	0.0219	0.0324	0.0428	0.0528	0.0626	0.0722	0.0816	0.0908	0.0998	0.1085				
14	0.0298	0.0442	0.0582	0.0719	0.0853	0.0983	0.1111	0.1236	0.1358	0.1477	0.1594	0.1709		
16	0.0389	0.0577	0.0760	0.0939	0.1114	0.1284	0.1451	0.1614	0.1774	0.1930	0.2082	0.2232		
18	0.0493	0.0730	0.0962	0.1188	0.1409	0.1625	0.1837	0.2043	0.2245	0.2442	0.2635	0.2824	0.3009	0.3190
20	0.0608	0.0901	0.1188	0.1467	0.1740	0.2007	0.2267	0.2522	0.2771	0.3015	0.3254	0.3487	0.3715	0.3939
22			0.1437	0.1775	0.2105	0.2428	0.2744	0.3052	0.3353	0.3648	0.3937	0.4219	0.4495	0.4766
24			0.1710	0.2113	0.2506	0.2890	0.3265	0.3632	0.3991	0.4342	0.4685	0.5021	0.5350	0.5672
26					0.2941	0.3391	0.3832	0.4263	0.4684	0.5096	0.5499	0.5893	0.6279	0.6657
28					0.3410	0.3933	0.4444	0.4944	0.5432	0.5910	0.6377	0.6834	0.7282	0.7720
30					0.3915	0.4515	0.5102	0.5675	0.6236	0.6784	0.7321	0.7846	0.8359	0.8862
32						0.5137	0.5805	0.6457	0.7095	0.7719	0.8329	0.8926	0.9511	1.0083
34						0.5799	0.6553	0.7289	0.8009	0.8714	0.9403	1.0077	1.0737	1.1383
36						0.6502	0.7346	0.8172	0.8979	0.9769	1.0542	1.1298	1.2037	1.2762
38						0.7244	0.8185	0.9105	1.0005	1.0885	1.1745	1.2588	1.3412	1.4219
40						0.8027	0.9070	1.0089	1.1086	1.2061	1.3014	1.3948	1.4861	1.5755
42						0.8850	0.9999	1.1123	1.2222	1.3297	1.4348	1.5377	1.6384	1.7370
44						0.9713	1.0974	1.2208	1.3414	1.4593	1.5747	1.6877	1.7982	1.9064
46						1.0616	1.1995	1.3343	1.4661	1.5950	1.7211	1.8446	1.9654	2.0836
48						1.1559	1.3060	1.4528	1.5963	1.7367	1.8741	2.0085	2.1400	2.2688
50							1.4171	1.5764	1.7321	1.8845	2.0335	2.1793	2.3220	2.4618
52								1.7050	1.8735	2.0382	2.1994	2.3571	2.5115	2.6627
54								1.8387	2.0204	2.1980	2.3719	2.5420	2.7084	2.8714
56								1.9774	2.1728	2.3639	2.5508	2.7337	2.9128	3.0880
58									2.3308	2.5357	2.7363	2.9325	3.1245	3.3126
60										2.7136	2.9282	3.1382	3.3437	3.5450
62										2.8976	3.1267	3.3509	3.5704	3.7852
64										3.0875	3.3317	3.5706	3.8044	4.0334
66										3.2835	3.5432	3.7972	4.0459	4.2894
68										3.4855	3.7611	4.0309	4.2948	4.5533
70											3.9856	4.2715	4.5512	4.8251
72											4.2166	4.5190	4.8150	5.1047
74											4.4542	4.7736	5.0862	5.3923

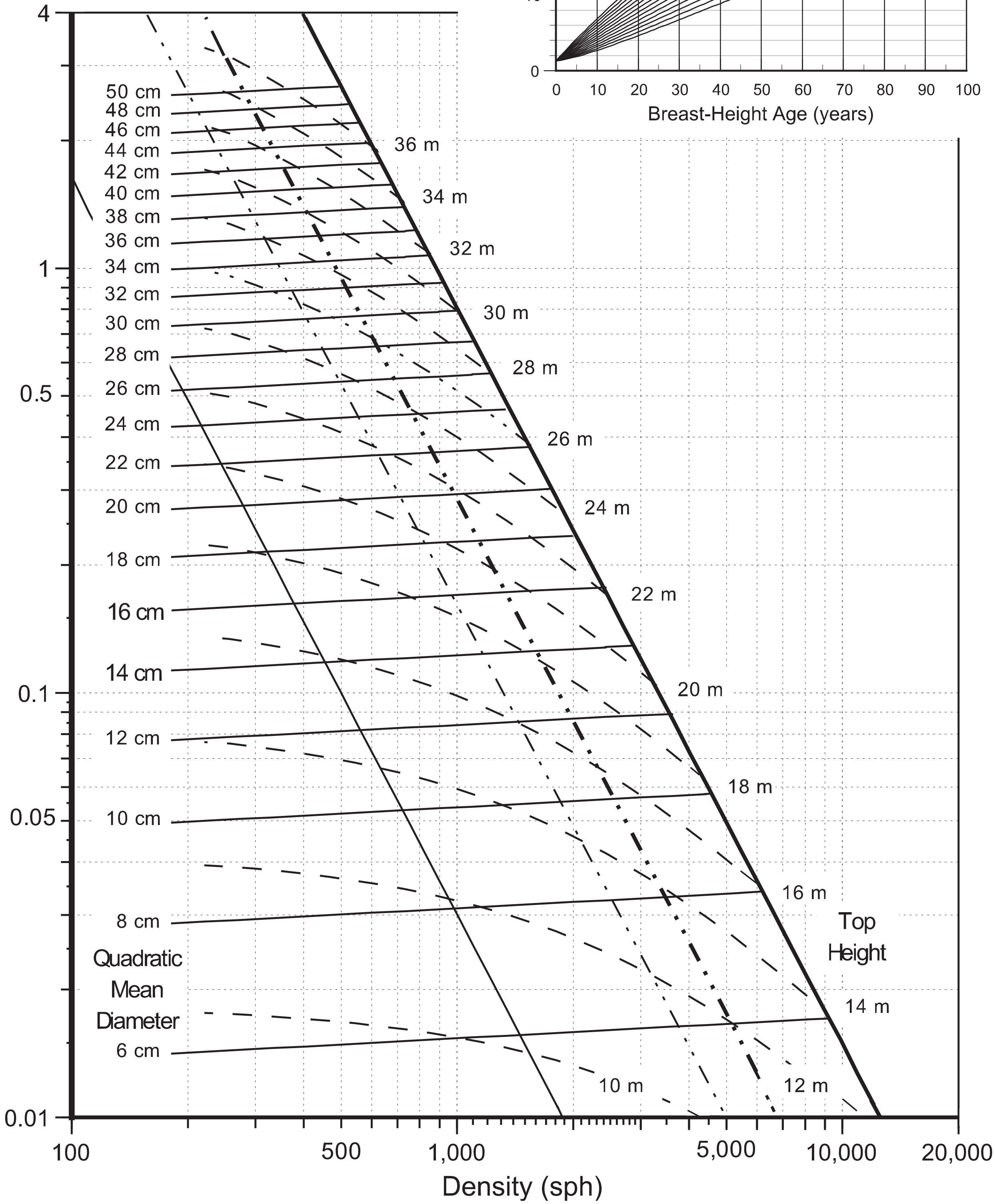
Honer's (1967) Total cubic meter volume equation

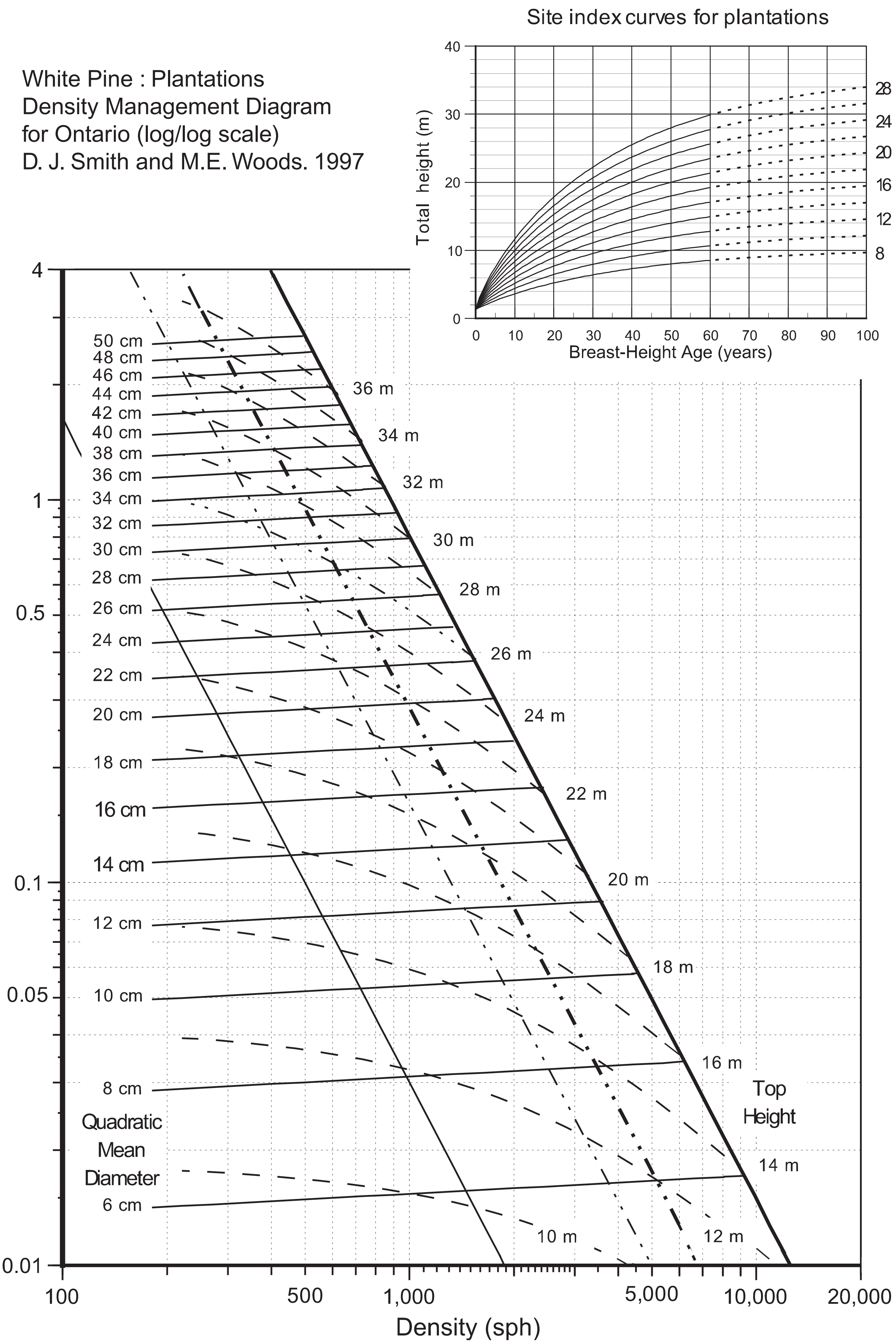
Volume (m^3) = $0.0043891 * dbh^2 * (1 - 0.04365 * 0.184)^2 / (0.691 + (0.3048 * 363.676 / Height))$ +/- 16.5% Accuracy

1169 Trees

White Pine : Natural Stands
Density Management Diagram
for Ontario (log/log scale)
D. J. Smith and M.E. Woods. 1997

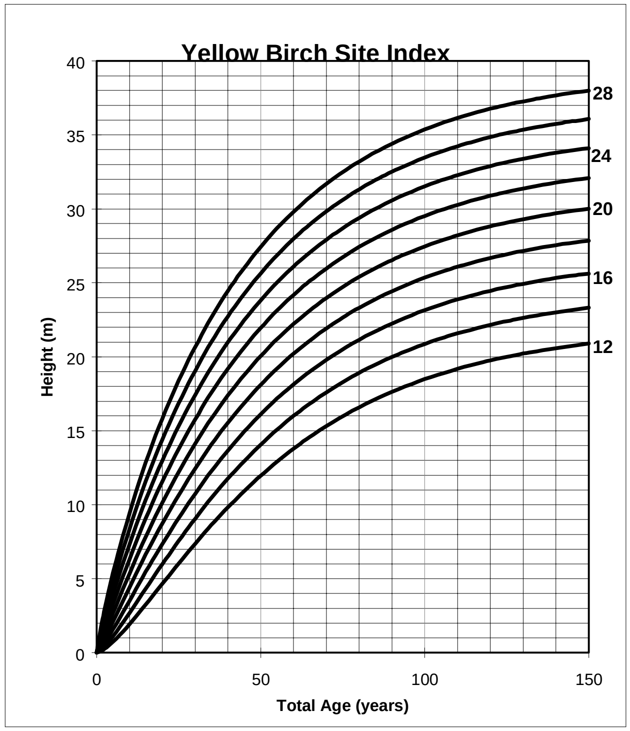





White Pine : Plantations
Density Management Diagram
for Ontario (log/log scale)
D. J. Smith and M.E. Woods. 1997
Site index curves for plantations
Total height (m)
Breast-Height Age (years)
Site Index
0
10
20
30
40
50
60
70
80
90
100
8
12
16
20
24
28
4
1
0.5
0.1
0.05
0.01
50 cm
48 cm
46 cm
44 cm
42 cm
40 cm
38 cm
36 cm
34 cm
32 cm
30 cm
28 cm
26 cm
24 cm
22 cm
20 cm
18 cm
16 cm
14 cm
12 cm
10 cm
8 cm
6 cm
Quadratic
Mean
Diameter
36 m
34 m
32 m
30 m
28 m
26 m
24 m
22 m
20 m
18 m
16 m
14 m
12 m
10 m
Top
Height
100
500
1,000
5,000
10,000
20,000
Density (sph)

Yellow Birch Growth & Yield Factsheet

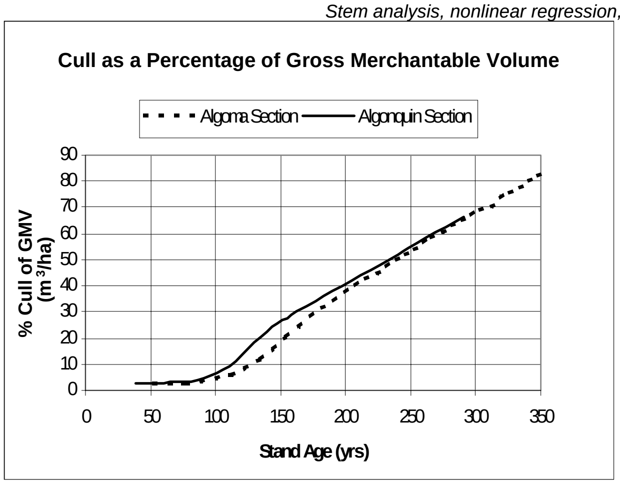
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.74	1.13	1.58	2.11	2.68	3.30	3.97	4.67	5.40
10	1.93	2.68	3.52	4.41	5.35	6.34	7.35	8.39	9.45
15	3.27	4.33	5.46	6.64	7.85	9.08	10.33	11.59	12.86
20	4.65	5.98	7.34	8.73	10.13	11.55	12.97	14.39	15.81
25	6.03	7.56	9.11	10.66	12.22	13.78	15.33	16.87	18.39
30	7.36	9.06	10.75	12.44	14.12	15.78	17.43	19.05	20.67
35	8.63	10.46	12.27	14.06	15.83	17.58	19.30	21.00	22.67
40	9.82	11.76	13.67	15.54	17.39	19.20	20.98	22.73	24.45
45	10.93	12.96	14.95	16.89	18.79	20.65	22.48	24.27	26.03
50	11.96	14.06	16.11	18.11	20.05	21.96	23.82	25.65	27.44
55	12.91	15.07	17.17	19.21	21.19	23.13	25.02	26.87	28.69
60	13.79	16.00	18.13	20.20	22.22	24.18	26.10	27.97	29.81
65	14.59	16.83	19.00	21.10	23.14	25.13	27.06	28.95	30.80
70	15.32	17.60	19.79	21.91	23.97	25.98	27.93	29.83	31.69
75	15.98	18.29	20.50	22.65	24.72	26.74	28.70	30.62	32.49
80	16.58	18.91	21.15	23.30	25.39	27.42	29.39	31.32	33.20
85	17.13	19.48	21.73	23.90	26.00	28.03	30.02	31.95	33.84
90	17.63	19.99	22.25	24.43	26.54	28.58	30.57	32.51	34.40
95	18.08	20.45	22.72	24.91	27.03	29.08	31.07	33.02	34.91
100	18.49	20.87	23.15	25.34	27.47	29.52	31.52	33.47	35.37
105	18.85	21.24	23.53	25.73	27.86	29.92	31.92	33.87	35.78
110	19.18	21.58	23.88	26.08	28.21	30.28	32.28	34.24	36.15
115	19.48	21.89	24.19	26.40	28.53	30.60	32.61	34.56	36.47
120	19.75	22.16	24.46	26.68	28.81	30.89	32.90	34.86	36.77
125	20.00	22.41	24.71	26.93	29.07	31.14	33.16	35.12	37.03
130	20.22	22.63	24.94	27.16	29.30	31.37	33.39	35.35	37.27
135	20.41	22.83	25.14	27.36	29.51	31.58	33.60	35.56	37.48
140	20.59	23.01	25.32	27.55	29.69	31.77	33.79	35.75	37.67
145	20.75	23.17	25.49	27.71	29.86	31.94	33.95	35.92	37.84
150	24.47	27.31	29.99	32.54	34.98	37.33	39.60	41.79	43.92

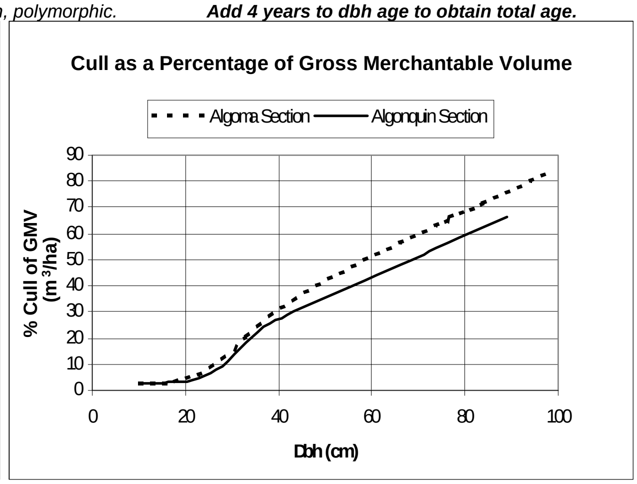


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{\wedge}b5)}]*.3048$

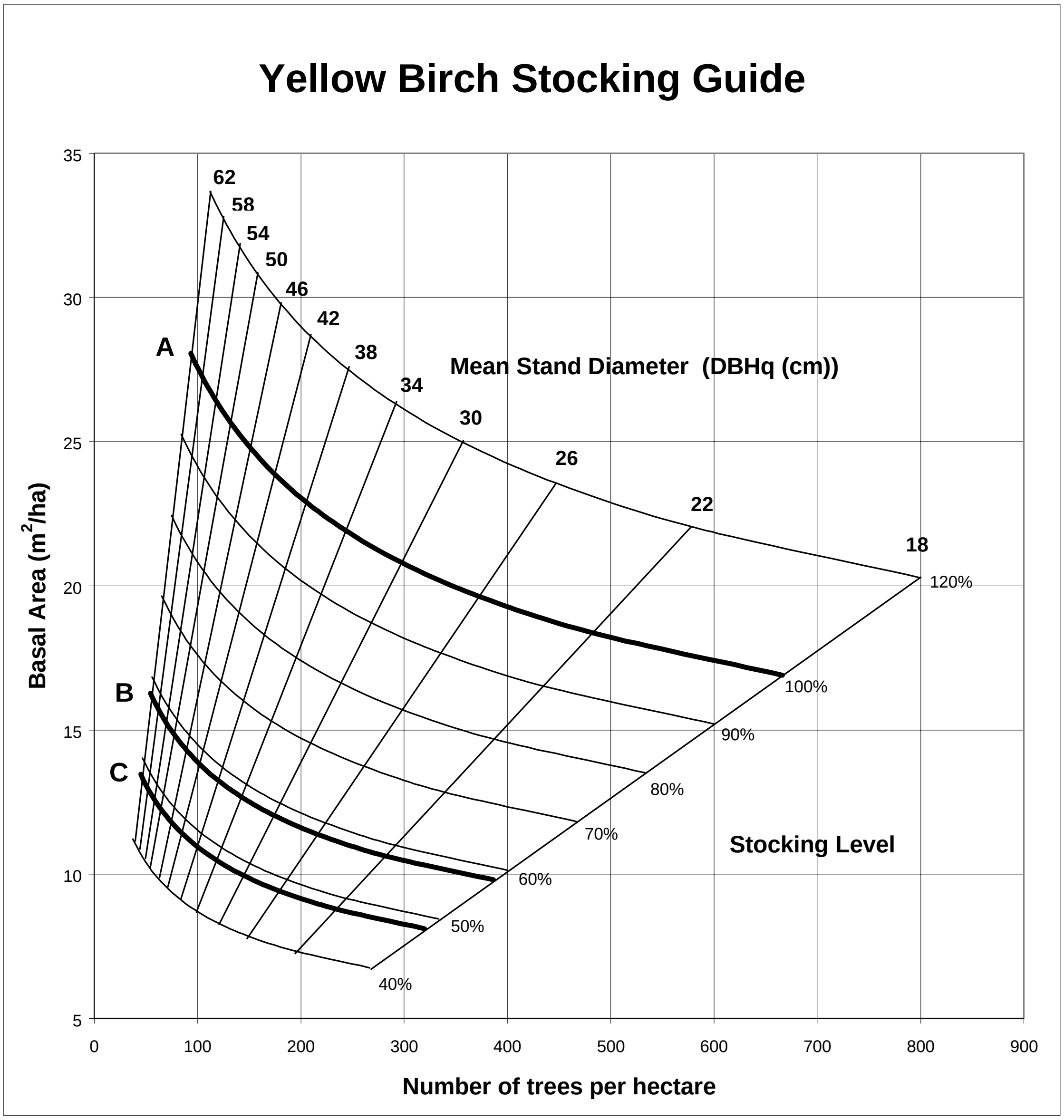
	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.0522	0.6768	-0.0217	15.4232	-0.6354	0.99	0.39	1.5
SI	0.1817	1.2430	-0.0110	-3.0184	-0.3180	0.98	0.62	2.3

Data Source: Carmean 1978. Northwest Wisconsin and Upper Michigan. 119 plots having 459 dominant and Codominant trees.
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***





Data Source:Morawski, Z.J.R. 1978 1418 Trees



(from Crow and Erdman)

	120%		A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	800	20.3	666	16.9	600	15.2	533	13.5	466	11.8	387	9.8	333	8.5	320	8.1
22	581	22.0	484	18.3	436	16.5	388	14.7	339	12.8	281	10.6	242	9.2	233	8.8
26	446	23.6	372	19.6	334	17.7	297	15.7	260	13.8	215	11.4	186	9.8	178	9.4
30	355	25.0	296	20.8	266	18.8	237	16.7	207	14.6	172	12.1	148	10.4	142	10.0
34	291	26.3	243	21.9	218	19.7	194	17.5	170	15.4	141	12.7	121	11.0	116	10.5
38	244	27.5	203	23.0	183	20.7	163	18.4	142	16.1	118	13.3	102	11.5	98	11.0
42	208	28.7	173	23.9	156	21.5	139	19.1	121	16.7	101	13.9	87	12.0	83	11.5
46	180	29.8	150	24.8	135	22.3	120	19.9	105	17.4	87	14.4	75	12.4	72	11.9
50	158	30.8	131	25.7	118	23.1	105	20.5	92	18.0	76	14.9	66	12.8	63	12.3
54	140	31.8	116	26.5	105	23.9	93	21.2	81	18.6	67	15.4	58	13.3	56	12.7
58	125	32.8	104	27.3	93	24.6	83	21.8	73	19.1	60	15.8	52	13.6	50	13.1
62	112	33.7	93	28.1	84	25.2	75	22.4	65	19.6	54	16.3	47	14.03	45	13.5

Yellow Birch Standard Volume Table (m^3)

Dbh	Total Tree Height (m)													
(cm)	4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0228	0.0296	0.0361	0.0423	0.0482	0.0539	0.0593	0.0644	0.0694	0.0741	0.0787	0.0830	0.0872
12	0.0224	0.0328	0.0427	0.0520	0.0610	0.0695	0.0776	0.0854	0.0928	0.0999	0.1068	0.1133	0.1196	0.1256
14	0.0305	0.0447	0.0581	0.0708	0.0830	0.0946	0.1056	0.1162	0.1263	0.1360	0.1453	0.1542	0.1628	0.1710
16	0.0399	0.0583	0.0758	0.0925	0.1084	0.1235	0.1380	0.1518	0.1650	0.1776	0.1898	0.2014	0.2126	0.2233
18	0.0505	0.0738	0.0960	0.1171	0.1371	0.1563	0.1746	0.1921	0.2088	0.2248	0.2402	0.2549	0.2691	0.2827
20	0.0623	0.0911	0.1185	0.1445	0.1693	0.1930	0.2156	0.2371	0.2578	0.2776	0.2965	0.3147	0.3322	0.3490
22	0.0754	0.1103	0.1434	0.1749	0.2049	0.2335	0.2608	0.2869	0.3119	0.3359	0.3588	0.3808	0.4019	0.4223
24		0.1312	0.1706	0.2081	0.2438	0.2779	0.3104	0.3415	0.3712	0.3997	0.4270	0.4532	0.4784	0.5025
26			0.2002	0.2442	0.2861	0.3261	0.3643	0.4008	0.4357	0.4691	0.5011	0.5319	0.5614	0.5898
28				0.2833	0.3319	0.3782	0.4225	0.4648	0.5053	0.5440	0.5812	0.6169	0.6511	0.6840
30				0.3252	0.3810	0.4342	0.4850	0.5336	0.5800	0.6245	0.6672	0.7081	0.7474	0.7852
32				0.3700	0.4335	0.4940	0.5518	0.6071	0.6600	0.7106	0.7591	0.8057	0.8504	0.8934
34					0.4893	0.5577	0.6230	0.6853	0.7450	0.8022	0.8570	0.9095	0.9600	1.0085
36					0.5486	0.6252	0.6984	0.7683	0.8353	0.8993	0.9608	1.0197	1.0763	1.1307
38						0.6966	0.7782	0.8561	0.9306	1.0020	1.0705	1.1361	1.1992	1.2598
40						0.7719	0.8622	0.9486	1.0312	1.1103	1.1861	1.2589	1.3288	1.3959
42						0.8510	0.9506	1.0458	1.1369	1.2241	1.3077	1.3879	1.4650	1.5390
44						0.9340	1.0433	1.1478	1.2477	1.3435	1.4352	1.5233	1.6078	1.6890
46						1.0208	1.1403	1.2545	1.3637	1.4684	1.5687	1.6649	1.7573	1.8461
48						1.1115	1.2416	1.3659	1.4849	1.5988	1.7080	1.8128	1.9134	2.0101
50						1.2061	1.3472	1.4821	1.6112	1.7348	1.8533	1.9670	2.0762	2.1811
52						1.3045	1.4571	1.6031	1.7427	1.8764	2.0046	2.1275	2.2456	2.3591
54						1.4068	1.5714	1.7288	1.8793	2.0235	2.1617	2.2943	2.4217	2.5440
56						1.5129	1.6899	1.8592	2.0211	2.1762	2.3248	2.4674	2.6044	2.7359
58						1.6229	1.8128	1.9944	2.1680	2.3344	2.4938	2.6468	2.7937	2.9349
60							1.9400	2.1343	2.3201	2.4982	2.6688	2.8325	2.9897	3.1408
62								2.2789	2.4774	2.6675	2.8497	3.0245	3.1923	3.3536
64								2.4283	2.6398	2.8424	3.0365	3.2228	3.4016	3.5735
66									2.8074	3.0228	3.2292	3.4273	3.6175	3.8003
68									2.9801	3.2087	3.4279	3.6382	3.8401	4.0341
70										3.4003	3.6325	3.8554	4.0693	4.2749
72										3.5974	3.8431	4.0788	4.3052	4.5227
74										3.8000	4.0595	4.3086	4.5477	4.7774

Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891*dbh^2 * (1-0.04365*0.181)^2 / (1.449+(0.3048*344.754/Height))$ +/- 34.3% Accuracy

Denotes range of data 1733 Trees

A

abiotic factors. The non-living components of the environment, such as air, rocks, soil, water, peat and plant litter.

achene. A small, dry, non-splitting one-seeded fruit, with distinct seed attached to the ovary wall at only one point.

accipiters. Long-tailed hawks with short, rounded wings that fly with several short quick beats and a sail rather than soaring in circles high in the air.

acre. An imperial measure of land area equal to 43,560 square feet, 4046.7 m^2 or 0.4 ha.

advance growth. Young trees that have become established naturally in a forest before cutting or regeneration begin.

advanced regeneration. Trees that have become established naturally under a mature forest canopy and are capable of becoming the next crop after the mature crop is removed.

adventitious. Arising from unusual positions, as in buds on roots.

age.

- *of a tree*:
    - **breast height**: the number of annual growth rings between the bark and the pith, as counted at breast height.
    - **harvest**: the number of years required to grow from establishment to maturity.
    - **stump**: the number of annual growth rings between the bark and the pith, as counted at stump height.
    - **total**: the number of years elapsed since the germination of the seed or the budding of the sprout or root sucker.

- *of a forest, stand or forest type, the average of the trees comprising it*:
    - **harvest**: The number of years between the establishment and the final harvest of a forest crop.
    - **total**: The average total age of the trees comprising it.

age class. One of the intervals into which the range of age classes of trees in a stand are divided into for classification and use.

AGS - *acceptable growing stock*. Trees suitable for retention in the stand for at least one cutting cycle (15 to 25 years). They are trees of commercial species and of such form and quality as to be saleable for sawlog products at some future date.

all-aged. Applies to a stand that contains trees of all ages.

all-aged management. A system of growing forest trees in groups where the individual trees are not the same age (theoretically, an all-aged forest has trees scattered throughout that range in age from one year to the oldest tree, whatever its age may be).

allowable cut. The volume of wood that may be harvested, under management, for a given period.

annual ring. The growth layer of one year, as viewed on the cross section of a stem, branch, or root. One year's growth consists of a layer of lighter-coloured wood (springwood) and a layer of darker-coloured wood (summerwood).

ANSI - *areas of natural and scientific interest*. Areas of land and water containing natural landscapes or features that have been identified by the Ontario ministry of Natural Resources as having life science or earth science values related to protection, scientific study or education.

AOC - ***area of concern***. An area adjacent to an identified value that may be affected by some (or all) aspects of forest management activity.

aquatic system. Areas where water levels are greater than 2 m in depth.

artificial regeneration. Renewal of a tree crop by direct seeding or by planting seedlings or cuttings.

aspect. The direction towards which a slope faces.

asexual. Referring to any type of reproduction which does not involve the union of sex-cells (gametes).

audit. A formal examination of an organization's or individual's performance.

autecology. Autecology refers to the study of the ecology of a single species. It refers to information on the biological behaviour of a plant species essential to understanding its growth, reproduction and response to disturbance and essential to choosing appropriate silvicultural treatments. It includes information about a species: habitat requirements, modes of reproduction, phenology, and response to disturbance.

B

basal area.

- *of a tree*:
    - the cross-sectional area of the bole of a tree, 1.3 m above the ground. Basal area = diameter of tree (cm) squared, times 0.00007854. (Expressed in m^2).
- *of a stand of trees*:
    - the sum of all the individual tree basal areas for a given land area. Commonly expressed as m^2/ha.

berry. A pulpy, non-splitting fruit developed from a single pistil and containing one or more seeds.

biodiversity - ***biological diversity***. The variety and variability (in time and space) among living organisms and the ecological complexes in which they occur.

biomass. The dry weight of all organic matter in a given ecosystem. It also refers to plant material that can be burned as fuel.

biota. All living organisms of an area, taken collectively.

blowdown (**windthrow**). Uprooting by the wind. Also refers to a tree or trees so uprooted.

board foot (bd. ft.). A volume measure of lumber, being one foot wide, one foot long and one inch thick.

bole. The main trunk of a tree.

breast height. The standard height, 1.3 m above ground level, at which diameter of a standing tree is measured.

broadleaf. ***see*** *hardwood.*

browse. Small bushes, sprouts, herbaceous plants, small trees, etc. that wildlife feed on.

brush. Commonly refers to undesirable shrubs and other low-lying vegetation.

buck. Cutting a felled tree into specified log lengths for yarding and hauling; also, making any bucking cut on logs.

buffer. A zone or strip of land that shields one area from another. Commonly used along streams or as visual barriers

bumper tree. A poor-quality, low-value tree that grows in close proximity to higher-value trees. Skid roads should be located next to bumper trees in order to protect residual trees from damage during a logging operation.

burl. An abnormal growth on a tree stem, with wood tissue growing in an irregular pattern. Usually circular in shape, these growths are widely sought for their interesting grain pattern.

butt. The base of a tree or log.

C

caliper. An instrument used to measure diameters of trees or logs. It consists of two parallel arms at right angles to a graduated rule, with one arm that slides along the rule.

calyx. The outermost group of floral parts.

cambium. A layer of cells between the woody part of the tree and the bark. Division of these cells results in diameter growth of the tree through formation of wood cells (xylem) and inner bark (phloem).

Canadian Shield. The Precambrian-aged, continental mass of the earth's crust centred on the Hudson Bay area, and which is comprised of mostly crystalline rocks in comparison with the surrounding younger, mostly stratified rock.

canker. Dead area of a branch or stem caused by fungal or bacterial attack.

canopy. A collective term for the layer formed by the crowns of the taller trees in a forest.

canopy closure. The progressive reduction of space between crowns as they spread laterally, increasing canopy cover.

canopy gap. A hole in the forest canopy that allows light penetration to the forest floor. Can be formed by naturally falling trees, standing dead trees and logging practices.

capsule. A dry, usually many seeded fruit that splits at maturity to release its seeds.

Carolinian species. A species whose range is restricted entirely to the Carolinian zone.

Carolinian zone. Also known as the Deciduous Forest Region of Canada and recognized as one of the most significant and threatened landscapes in the country.

caryopsis. A simple, dry, one-sided, non-splitting fruit with seed firmly attached to the entire ovary wall.

catkin. A scaly spike bearing inconspicuous and usually unisexual flowers.

cavity. An unfilled space within a mass, a hollowed out space. In forestry and wildlife there are several categories of cavity trees, each with their own importance in the ecosystem:

- **Pileated woodpecker roost cavities**: First priority for retention are living or standing dead trees with cavities used by pileated woodpeckers for roosting. These are usually large (40+ cm DBH) diameter trees that are hollow and have at least two excavated entrance holes. These holes are somewhat oval, about 7.5 to 10 cm wide and 10 to 12.5 cm high. Holes are symmetrically oval, smooth edged and deep.
- **Pileated woodpecker nest cavities**: Second priority for retention are living trees with cavities used by pileated woodpeckers for nesting. These are usually large (40+ cm DBH) diameter trees in which pileated woodpeckers have excavated one or more nest chambers and associated entrance holes. Nest and roost trees can be distinguished by the number of entrance holes and tree condition. Roost trees may have 2 to 10+ entrance holes and entrance holes may be less than 1 m apart. Condition is probably the best clue to separate nest and roost trees. Pileated woodpeckers excavate nest cavities in trees with white spongy heart rot (not trees with existing hollows). Roost cavities are in hollow trees (look for seams, barreling, etc. to indicate hollowness).
- **Other woodpecker nest cavities or natural nest or maternal den cavities**: The third priority for retention are living trees with cavities excavated by other woodpeckers (e.g. yellow-bellied sapsucker, hairy woodpecker, northern flicker) for nesting or cavities suitable for nesting or denning (by secondary cavity users) that formed from natural decay processes.
- **Escape cavity**: The fourth priority for retention are living trees with natural cavities that provide temporary shelter, escape from predators, food-caching sites, or resting/loafing/roosting sites. They are not ideal for nests or dens because of location, size, entrance hole size, or orientation.
- **Feeding cavity**: The fifth priority for retention are living trees with feeding excavations created by woodpeckers in search of food. They are generally rectangular, semi-circular, or irregular. Holes do not typically enlarge into chambers suitable for nesting or escape. Edges and surfaces tend to be rough.
- **Potential cavity tree**: Trees with potential to attract excavators or develop natural cavities. Typically they have evidence of advanced heart rot. These living trees are retained when situations arise in areas that do not have at least 6 existing cavities per hectare left after tree marking.

cleaning. Elimination or suppression of competing vegetation from stands not past the sapling stage; specifically, removal of:

- weeds, climbers, or sod-forming grasses, as in plantations; or
- trees of similar age or of less desirable species or form than the crop trees, which they are, or may soon, be, overtopping.

clearcut. An area on which the entire timber stand has been harvested. ***see*** *reproduction methods.*

clear-length. Branch-free length of the bole.

climax vegetation. The final stage of natural plant succession, in which the plant composition remains relatively stable.

clone. All plants reproduced asexually from a common ancestor and having identical genotypes. (genetically identical to the parent plant) (e.g. from cuttings or suckers).

codominant trees. Trees with crowns forming the general level of the crown cover and receiving full light from above, but comparatively little from the sides; usually with medium size crowns. ***see*** *crown class.*

commercial thinning. Removing trees from a developing young stand, so that remaining trees will have more growing space; dead and dying trees will be salvaged; and the operation will make a net profit.

community. An integrated group of species inhabiting a given area and influencing one another's distribution, abundance and evolution.

Community Series I. Level 3 of the Ecological Land Classification system that describes various communities such as forests, swamps, savannahs according to their respective patterns of dominant species, substrate type, geology, microclimate, and other ecological factors.

Community Series II. Level 4 of the Ecological Land Classification system that describes communities that can normally be recognized on aerial photographs or from a combination of maps, aerial photograph interpretation, and other remote sensing techniques.

competition. The general struggle for existence within a trophic level in which the living organisms compete for a limited supply of the necessities of life.

composition. The representation of tree species in a forest stand, expressed quantitatively as per cent by volume or basal area of each species.

cone. The male or female reproductive organs of conifers.

conifer. A tree belonging to the order Coniferae, usually evergreen with cones, needle-shaped leaves and producing wood known commercially as 'softwood.'

conk. A hard, spore-bearing structure of a wood-destroying fungus that projects beyond the bark of a tree.

conservation. In forestry, the wise use of natural renewable resources. A key idea for understanding 'conservation' is 'use' by people.

conventional ground skidding. Any combination of rubber-tired or tracked skidding equipment.

coppice. A shoot (sprout) originating from a stump.

cord. 128 cubic feet of stacked roundwood (whole or split, with or without bark) containing wood and airspace, with all the pieces of similar length and lined up on approximately the same direction. i.e. a pile of firewood 4'x 4' x 8'.

corridor. A band of vegetation, usually older forest, which serves to connect distinct patches on the landscape. Corridors provide connectivity, which permits the movement of plant and animal species between what would otherwise be isolated patches.

cover. Vegetation or other material providing protection. Plants or objects used by wild animals for nesting, rearing of young, resting, escape from predators, or protection from adverse environmental conditions.

critical wildlife habitat. Part or all of a specific place occupied by a wildlife species or a population of such species and recognized as being essential for the maintenance of the population.

crook. A defect in logs and poles or pilings, consisting of an abrupt bend. Also refers to edgewise warp in a piece of lumber.

crop tree. A tree selected in a young stand, to be retained until final harvest.

crotch. The fork of a tree or branch.

crown. The branches and foliage of a tree.

crown class. A designation of trees in a forest with crowns of similar development and occupying similar positions in the crown cover. Differentiation into crown classes applies to even-aged stands and within small even-aged groups in which trees in an uneven-aged stand are often arranged. Five crown classes are commonly recognized: dominant, codominant, intermediate, overtopped (suppressed), and wolf trees.

crown closure. The time at which the available crown space has become fully occupied.

crown cover. The canopy of green leaves and branches formed by the crowns of all trees in a forest. Generally expressed as a per cent of total area.

crown density. The compactness of the crown cover of the forest; depends on the distance apart and the compactness of the individual crowns. A loose term combining the meanings of 'crown closure' and 'shade density.'

crown touching method. Each crop tree receives a full crown release by eliminating adjacent trees that touch the crop tree crown by cutting or by killing the these trees through girdling or herbicides.

cruising. Measuring standing trees to determine the volume of wood on a given tract of land. Used for harvesting, purchasing and general management.

cubic meter (m^3). A volume measure, 1 m by 1 m by 1 m.

cull. A tree or log of merchantable size rendered unmerchantable because of poor form, large limbs, rot, or other defects.

cull tree. A live tree of merchantable size but unmerchantable because of defects or decay.

cutting area. A portion of woodland on which timber is being cut or will be cut.

cutting cycle. The planned interval between major harvesting operations in the same stand. A 20-year cutting cycle indicates a harvest is done once every 20 years.

D

DBH - *diameter at breast height*. The diameter of a tree outside of the bark at roughly breast height. Normally measured 1.3 m off the ground on the uphill side of the tree. It is easier to measure at this height and many trees have large swells in the stem below this point that could increase errors in computing tree volumes.

deciduous. Term applied to trees (commonly broad-leaved trees) that drop all their leaves sometime during the year.

decline causing defects. Mechanical or pathological defects that may cause decline or cause the tree to be of high risk. These defects will also cause the decline of the products which may be recovered from a tree or severely limit the potential of a tree to produce anything better than low-value products.

defect. Any irregularity or imperfection in a tree, log, piece, product, or lumber that reduces the volume of sound wood or lowers its durability, strength, or utility value.

defect class. A system of categorizing tree defects by severity of degradation of the tree and/or the merchantable portion of the tree over time:

- **major defect**: The tree will degrade rapidly.
- **moderate defect**: The tree will degrade slowly.
- **minor defect**: The tree will maintain quality over cutting cycle period.

defoliator. An agent that damages trees by destroying leaves or needles.

den tree. A tree having a hollow or cavity used by animals for refuge or hibernation.

dendro-ecology. The study of annual growth rings of trees to assess the conditions in which a tree has grown (an application to assess ecosystem health).

determinate growth. Also known as 'fixed' shoot growth, refers to shoot growth pattern where growth occurs through elongation of pre-formed stem parts, or 'stem units' after a rest period. In determinate tree species, shoot formation involves differentiation in the bud the first year (n) and extension of the preformed parts into a shoot during the second year (n + 1). In determinate species, the growing season during bud formation largely determines the potential size of shoot and number of leaves formed the following year. Examples: white and red pine, spruces, fir, beech.

diameter class. One of the intervals into which the range of diameters of trees in a forest is divided for purposes of classification and use. Generally this is done in 2 cm, even increments (40 cm class would contain trees from 39.1 to 41.0 cm)

diameter limit. The smallest (occasionally the largest), size to which trees or logs are to be measured, cut, or used. The points to which the limit usually refer are stump, breast height, or top.

diameter-limit cutting. A system of selection harvest based on cutting all trees in the stand over a specified diameter. This eliminates marking individual trees. This is not a recognized silvicultural system in Ontario.

dioecious. Producing male and female reproductive organs on separate plants. Each plant is either male or female.

disease. Harmful deviation from normal functioning of physiological processes, generally pathogenic or environmental in origin.

dominant trees. Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side; larger than the average trees in the stand, with crowns well developed, possibly somewhat crowded on the sides. ***see*** *crown class*.

dormancy.

- A biological process in which a plant ceases most growth activities and simply maintains existing tissue. Caused by periods of moisture and/or temperature stress.
- A state of reduced activity in seeds that prevents germination under favorable environmental conditions.

downed woody debris (**DWD**). Sound and rotting logs and stumps that provide habitat for plants, animals and insects and a source of nutrients for soil development.

drumlin. Elongated oval or 'whale-back' ridge of deep molded glacial till formed during ice advance and with long axis parallel to ice movement.

drupe. A fleshy, usually one-seeded fruit whose seed is completely enclosed in a hard, bony endocarp.

dry rot. A decay of the "brown rot" type, caused by specialized fungi capable of conducting moisture from an available source and extending their attack to wood previously too dry to decay. Found chiefly in buildings. The term is open to the misinterpretation that wood will rot when dry, which is not true.

duff. Forest litter and other organic debris in various stages of decomposition on top of the mineral soil; typical of coniferous forests in cool climates, where rate of decomposition is slow and where litter accumulation exceeds decay.

E

ecology. The science that deals with the interaction of plants and animals with their environment.

Ecological land Classification (ELC). A system devised by OMNR to describe over 80 wetland and terrestrial forest vegetation types in southern Ontario. This preliminary community classification system has six different organizational levels.

ecosite. The fifth organizational level that identifies a site based on bedrock type, soil depth, texture, and moisture regime, hydrology, drainage, nutrient regime, and vegetation structure and species composition.

ecosystem. A functional unit consisting of all the living organisms (plants, animals and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size—a log, pond, field, forest, or the earth's biosphere—but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation, for example, forest ecosystem, old-growth ecosystem, or wetland ecosystem.

ecosystem management. The use of an ecological approach to achieve productive resource management by blending social, physical, economic and biological needs and values to provide healthy ecosystems.

edge. The transitional zone where one cover type ends and another begins.

endangered species. A species of native fish, wildlife, or plants found to be threatened by extinction because its habitat is threatened with destruction, drastic modification, or severe curtailment, or because of over-exploitation, disease, predation, or other factors its survival requires assistance.

endocarp. The inner wall layer of a ripened ovary.

environment. All elements living and inanimate, that affect a living organism.

ESAs -*environmentally sensitive areas*. A general term for natural areas whose significance has been assessed on the basis of a series of qualitative criteria applied on a local or regional basis by municipalities, conservation authorities or others.

epicormic sprout. A branch rising spontaneously from an adventitious or dormant bud on the stem or branch of a woody plant.

epidemic. Widespread insect or disease incidence beyond normal proportions; usually accompanied by excessive damage.

even-aged. The conditions of a forest or stand composed of trees having no, or relatively small, differences in age, although differences of as much as 30 per cent are admissible in rotations greater than 100 years of age.

even-aged management. The application of a combination of actions that results in the creation of stands in which trees of essentially the same age grow together. The difference in age between trees forming the main canopy level of a stand usually does not exceed 20 per cent of the age of the stand at maturity. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for regeneration and is harvested. Cutting methods producing even-aged stands are clearcut, shelterwood, or seed-tree.

exotic. Not native; foreign.

F

felling and bucking. The process of cutting down standing timber and then cutting it into specific lengths for yarding and hauling.

final cutting. The removal of seed or shelter trees after regeneration has been effected, or removal of the entire crop of mature trees under a clearcut silvicultural system.

fire scar. An injury or wound in the bole of a tree caused or accentuated by fire.

fish habitat. Spawning grounds and nursery, rearing food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

fixed area plot sampling method. A controlled cruise method where small plots of a fixed size are used to sample a portion of a forest area to obtain information (such as tree volume) that can be used to describe the whole area.

fluxing. An abnormal discharge from a crack or seam.

forb. A small herbaceous plant, unlike grass.

forest. A plant community predominantly of trees and other woody vegetation, growing more or less closely together; An area managed for the production of timber and other forest products, or maintained under woody vegetation for such indirect benefits as protection of site or for recreation.

forest management. The application of business methods and technical forest principles to the management of forest property.

forest survey. An inventory of forest land to determine size, condition, timber volume and species, for specific purposes or as a basis for forest policies and programs. Also refers to carefully measuring and marking property boundaries.

forest type. A descriptive term used to group stands of similar character in composition and development, to differentiate them from other groups of stands.

forestry. The science, art and practice of managing and using for human benefit the natural resources that occur on and in association with forest lands.

form. The shape of a log or tree.

form class. A measure of bole taper derived by dividing diameter inside bark at a given height (usually 5.2 or 10.4 meters) by DBH. These values are often required to use tree-volume tables.

forwarder. A machine used to move short log lengths from the stump to the landing, often in a carrier that keeps the logs off of the ground.

fragmentation. The process of transforming large continuous forest patches into one or more smaller patches surrounded by disturbed areas. This occurs naturally through such agents as fire, landslides, windthrow and insect attack. In southern Ontario, agriculture and development have contributed to forest fragmentation.

free-to-grow. A condition in which a forest is considered established based on a minimum stocking standard, a minimum height and freedom from competition that could impede growth.

frost crack. Longitudinal crack on the outside of a tree, caused by extreme cold. Especially common on thin-barked species.

fruiting body. ***see*** *conk.*

fuelwood. Trees used for the production of firewood logs or other wood fuel.

full-tree harvesting. A tree harvesting process that includes removing the trunk, branches and in some instances the roots from a forested site. In Canada this process is used to control root diseases.

fungus. A plant without chlorophyll that derives its nourishment from the organic matter of other plants.

G

gall. A pronounced localized swelling of greatly modified structure that occurs on plants from irritation by a disease or insect.

gallery. A passage or burrow, excavated by an insect under bark or in wood for feeding or egg-laying purposes.

gap. A site at which a canopy tree has died and at which active recruitment of new individuals into the canopy is occurring.

gap phase replacement. Refers to the dynamic ongoing process in undisturbed tolerant hardwood stands in which canopy gaps are continually created by the death or destruction of mature trees. The gap becomes the site of increased regeneration and survival and eventually is occupied by trees reaching into the upper canopy.

gene pool. Sum of all genes among scattered populations of a given species.

genetic diversity. The diversity of genes among members of the same species or population.

genotype. The entire genetic constitution, or the sum total of genes of an organism. The genotype interacts with the environment to produce an individual whose appearance is referred to as the phenotype.

germination. The resumption of active growth in the embryo of a seed, as demonstrated by the protrusion of a radicle (embryonic root axis).

girdle. To encircle the stem of a living tree with cuts that completely sever bark and cambium and often are carried well into the outer sapwood, done to kill the tree by preventing the passage of carbohydrates to the roots. Also refers to same process caused by animals, such as mice or beavers.

glaze damage. Damage to tree caused by ice or frost.

gley. A blue-gray colour in soil due to the reduction of iron. Formed in a process characterized by low oxygen conditions due to water logging. If water logging is seasonal rather than permanent, the periodic oxidation will give rise to mottles.

grade.
- A system of classifying lumber or logs according to quality.
- The steepness of a forest road.

grain. A small hard seed or seed-like fruit, as for any of the cereals.

gross total volume. Volume of the main stem of the tree including stump and top. Volume of the stand including all trees.

group selection. Modification of the selection system in which trees are removed in small groups rather than as individuals.

growing degree days (GDD). Accumulated number of degrees of mean daily temperature above a base temperature of 5.5 ^{O}C. This provides an index, which is used to estimate the growth and development of plants and insects during the growing season.

growing stock. The sum, by number or volume, of all the trees in a forest or a specified part of it.

growth. The increase in diameter, basal area, height or volume of individual trees or groups of trees during a given period.

growth rate. With reference to wood, the rate at which wood has been added to the tree at any particular point, usually expressed in the number of annual rings per centimeter. May also be stated as “annual leader growth.”

guild. Species which are grouped together because of common strategies and/or use of areas for life cycle stages.

H

habitat. The environment in which the plant or animal lives.

hardwood.
- Generally, one of the botanical group of trees that have broad leaves, in contrast to the needle-bearing conifers.
- Wood produced by broad-leaved trees, regardless of texture or density.

harvest. Extraction of some type of product from the forest. Generally associated with a cutting.

heart rot. A decay characteristically confined to the heartwood. It usually originates in the living tree.

heartwood. The inner core of a woody stem, wholly composed of non-living cells and usually differentiated from the outer enveloping layer (sapwood) by its darker colour.

hectare (ha). An area measure of 10,000 square meters. Basic unit of land area.

herb. A non-woody flowering plant.

high grading. The removal from the stand of only the best trees or tree species, often resulting in a poor quality residual stand.

hip. The fleshy, false fruit of the rose.

humus. The plant and animal residues of the soil (litter excluded) that have decomposed to the point where their origin is no longer recognizable.

hydric. A general term for soils that develop under conditions of poor drainage in marshes, swamps, seepage areas or flats.

I

ice damage. Breakage of tops and branches and stripping of branches and needles by an ice storm.

immature. Trees or stands that have grown past the regeneration stage, but are not yet mature.

improvement cutting. The elimination or suppression of less valuable trees in favor of more valuable trees, typically in a mixed, uneven-aged forest.

increment. An increase in the diameter, basal area, height, volume, quality, or value of individual trees or stands over time.

- **Current Annual Increment** (**CAI**): Growth increment in a given year of the diameter, basal area, height or volume for a given tree or group of trees.
- **Mean Annual Increment** (**MAI**): The average annual increment for the total age of the diameter, basal area, height or volume for a given tree or group of trees.

increment core. That part of the cross section of a tree extracted by an increment borer. Used to determine tree age and growth.

indeterminate growth. Also known as “free” shoot growth, involves elongation of a shoot by simultaneous initiation and elongation of new stem units. Indeterminate species exhibit continuous shoot growth as long as the environment is suitable. Examples: poplar, some maples, birch.

indicator species. Species of plants used to predict site quality and characteristics.

infection courts. Paths by which insects and disease can enter a tree, leading to defect and decay (e.g. wounds)

inflorescence. A floral axis with its appendages.

intermediate trees. Trees shorter than those in the dominant or codominant classes, but with crowns either below or extending into the crown cover formed by codominant and dominant trees; receiving a little direct light from above, but none from the sides; usually with small crowns, considerably crowded on the sides. ***see*** *crown class*.

intolerance. Trees unable to survive or grow satisfactorily under specific conditions, most commonly used with respect to their sensitivity to shade but also to conditions such as wind, drought, salt and flooding.

invasive exotic species. An invasive exotic species is a non-native plant or animal that threatens the survival of native species.

K

knot. That part of a branch that has been incorporated into the main stem.

L

landing. The area where logs are collected for loading for transport to a mill.

landscape. All the natural features, such as fields, hills, forests and water that distinguish one part of the Earth’s surface from another part; usually that portion of land or territory which the eye can comprehend in a single view, including all of its natural characteristics.

layering. The rooting of an undetached branch, lying on or partially buried in the soil or other forest floor media, that is capable of independent growth after separation from the parent plant.

leader. The growing top (terminal shoot) of a tree. The distance up the main stem of the tree between each whorl of branches generally represents one year of height growth.

leave tree. Tree left in or just outside a harvest zone (often otherwise a clearcut) to re-seed the area. This is nature's method of reforestation; but it is often slower and it does not have the more assured results of direct seeding or planting. May also refer to trees left after a thinning.

litter. The uppermost layer of the soil, made up of freshly fallen or slightly decomposed organic materials.

littoral zone. Shallow shoreline areas of a waterbody where light penetrates to the bottom and is often accompanied by rooted aquatic plants.

live crown ratio (**LCR**). The length of the crown as a ratio of the total height of the tree, usually expressed as a per cent.

log.
- To cut and deliver logs.
- A tree segment suitable for lumber and other products.

logger. A person who is engaged in a logging operation; locally, one who moves logs to landings or skidways.

log rule. A table showing the estimated or calculated amount of lumber that can be sawn from logs of given length and diameter.

log scale. The lumber content of a log as determined by a log rule.

M

management plan. A written plan for the organized handling and operation of a forest property. It usually includes data and prescribes measures designed to provide optimum use of forest resources according to the landowner's objectives.

marking timber. Selecting and indicating, usually by a paint mark, trees to be cut or retained in a harvesting or tending operation.

mast. The fruit and nuts of trees and woody shrubs used as a food source by wildlife.

mast trees. Trees supporting mast production, e.g. oak, beech, cherry.

maturity. For a given species or stand, the approximate age or condition beyond which the growth rate declines or decay begins to assume economic importance.

mean annual increment (**MAI**). The average annual increase in volume of individual trees or stands up to the specified point in time. The MAI changes with different growth phases in a tree's life, being highest in the middle years and then slowly decreasing with age. The point at which the MAI peaks is commonly used to identify the biological maturity of the stand and its readiness for harvesting.

mechanical site preparation. Any activity that involves the use of mechanical machinery to prepare a site for reforestation.

merchantable. That part of a tree that can be manufactured into a salable product.

merchantable height. The length of the tree stem from the top of the stump to the top of the last merchantable section. Usually expressed in meters or number of logs.

merchantable length. Length of the tree from which could be produced a merchantable product under given economic conditions.

merchantable timber. A tree or stand of trees that may be converted into salable products.

merchantable volume. The amount of wood in a single tree or forest stand that is considered salable.

mesic. Describing the sites that are neither humid (hydric) nor very dry (xeric). The average moisture conditions for a given climate.

meter (m). Measure of length equal to 100 cm.

metric chain. A 20 m measure.

microclimate. Generally the climate of small areas, especially insofar as this differs significantly from the general climate of the region. Stands often create microclimates.

microsite. A portion of a site that is uniform in microtopography and surface soil materials. It can range in size from less than 1 m^2 to occasionally over 5 m^2. Microsites are dynamic in that their characteristics are ever-changing, imperceptibly or suddenly.

mineral soil. Soil consisting predominately of, and having its properties determined by, inorganic matter. Usually contains less than 20 % organic matter.

monoecious. Bearing separate male and female flowers on the same tree.

mortality. Death of forest trees as a result of competition, disease, insect damage, drought, wind, fire and other factors.

mottles. Spots or blotches of different colour or shade of colour interspersed with the dominant soil colour, usually the result of alternating aerobic and anaerobic soil conditions and indicative of poor drainage. In surveying soils, the colour of the matrix and the principal mottles, and the pattern of mottling are noted. The latter is indicated in terms of abundance (few, common, many), size (fine, medium, coarse), and contrast with the matrix (faint, distinct, prominent). The depth of mottles in soils of different types is a diagnostic indication if moisture regime.

mycorrhiza. A rootlet of a higher plant modified through integral association with a fungus to form a constant structure that differs from either component but is attached to the root system and functions somewhat as a rootlet. It is usually considered to be beneficial to the associated plant.

N

natural regeneration. The renewal of a forest stand by natural seeding, sprouting, suckering, or, layering seeds may be deposited by wind, birds, or, mammals.

natural thinning. Death of trees in a stand as a result of competition.

needle cast. Premature browning and dropping of needles caused by a fungus.

NMV - ***net merchantable volume***. The result of removing volume associated with stain or decay from the gross merchantable volume or trees or cut timber.

nurse tree (**crop tree**). A tree or crop of trees, shrubs, or, other plants that foster another, generally a more important, tree or crop.

nut. A dry, non-splitting, one-seeded fruit with a woody or leathery outer surface, often encased in a husk.

nutlet. A small nut.

O

old growth. A relatively old forest that little or no evidence of human disturbance. This term is misapplied by many to describe any forest that appears to be old. Individual trees in this type of forest are usually over 200 years old and there are large standing and fallen dead trees throughout the stand.

operation. Used interchangeably for logging jobs, harvesting, cutting, milling, etc. An all-inclusive term for harvesting and hauling out the forest products.

organic litter. The layer of decomposing leaves, bark, twigs and other organic debris that lies on the forest floor.

organic soil. Soil containing a high proportion (greater than 20 or 30 per cent) of organic matter.

overmaturity. That period in the life cycle of trees and stands when growth or value is declining.

overstocked. A condition of the stand or forest, indicating more trees than desired, normal, or full stocking would require.

overstory. That portion of the trees in a stand forming the upper crown cover.

overtopped tree. Trees with crowns entirely below the general level of the overstory cover, receiving no direct light either from above or from the sides. Also known as suppressed. ***see*** *crown class*.

P

partial cutting. Refers generically to stand entries, under any of the several silvicultural systems, to cut selected trees and leave desirable trees for various stand objectives. Partial cutting includes harvest methods used for seed tree, shelterwood, selection and clearcutting with reserves systems.

patch cutting. A silvicultural system that creates openings less than 1 hectare in size and is designed to manage each opening as a distinct even-aged opening.

per cent grade.
- The vertical rise of land in 100 horizontal units. A 16 % grade means that in 100 m horizontal, the elevation has changed 16 m.
- Amount of forest volume found to be in a given log grade.

perfect. Having both functional male and female reproductive organs.

pest. A plant, animal, or thing that is troublesome or annoying (from a human value perspective).

phenology. Study of the relations between seasonal climatic changes and periodic biological phenomena, such as the flowering and fruiting of plants.

pH. A measure of the hydrogen ion on a scale of 0 (very acidic) to 14 (very basic). A pH value of 7 is neutral. Every change in one unit of measure indicates a 10x change in the quantity of hydrogen ions (e.g., a pH of 5.0 is 10x more acidic than a pH of 6.0 and 100x more acidic than a pH of 7.0).

phenotype. The visible characteristics of a plant. The product of the interaction of the genes of an organism (genotype) with the environment.

phloem. The tissues of the inner bark, characterized by the presence of sieve tubes and serving for the transport of elaborated foodstuffs.

photosynthesis. The conversion by green plants of light, water and air into food energy.

physiographic system. A system that comprises the inorganic portion of the environment outside of the works of man.

pioneer (**botanical**). A plant capable of invading bare sites (that is, a newly exposed soil surface) and persisting there until supplanted by successor species. A species planted to prepare a site for such successor species and therefore, a nurse crop.

plantation. An artificially reforested area established by planting or by direct seeding.

plot. A carefully measured area laid out for experimentation; may be permanent or temporary.

point sampling. A method of selecting trees for measurements and of estimating stand basal area at a sample location or point sample. Also called plotless cruising, angle count method. A 360^{o} sweep is made with an angle gauge about a fixed point and the stems with breast height diameters appearing larger than the fixed angle subtended by the angle gauge are included in the sample.

pole.

- A young tree between 10 and 25 cm in DBH.
- A log cut for the manufacture of utility poles (usually trees larger than 30 cm DBH).

polewood. Trees with a DBH between 10 and 25 cm.

pome. The apple-pear type of fruit, in which the true fruits are surrounded by an enlarged fleshy calyx tube and receptacle.

population sink. A habitat insufficient in size or resources to support a viable population of a species, yet which may attract dispersing individuals.

precommercial thinning. Removal of some of the trees in a young stand to reduce competition for water, nutrients and light and to accelerate commercial growth on remaining trees. Trees thinned from these stands have no commercial value.

pre-harvest silviculture assessment (**survey**). The survey carried out on a stand prior to logging to collect specific information on the silvicultural conditions such as planting survival, free-growing status, stocking, etc.

pre-harvest silviculture prescription. A document that applies site-specific field data and develops forest management prescriptions for areas in advance of logging.

preparatory cutting. The removal of trees near the end of a rotation, which permanently opens the canopy and enable the crowns of seed bearers to enlarge, to improve conditions for seed production and natural regeneration. Typically done in the shelterwood system.

prescribed burning. The knowledgeable application of fire to a specific unit of land to meet predetermined resource management objectives.

prescription. A course of management action prescribed for a particular area after specific assessments and evaluations have been made.

primary excavator (**tree cavity**). Animals that excavate their own cavities.

prism. A wedge-shaped piece of clear or amber-coloured glass that is used to select trees for timber sampling or to estimate basal area.

pruning. The removal of live or dead branches from standing trees, usually the lower branches of young trees and the removal of multiple leaders in plantation trees, for the improvement of the tree or its timber; the cutting away of superfluous growth, including roots, from any plant to improve its development. ***see*** *self-pruning.*

pulpwood. Wood cut or prepared primarily for manufacture into wood pulp, for later manufacture into paper, fibreboard, or other products.

punky. A soft, weak, often spongy condition in wood; caused by decay.

Q

Q-value. The relationship between number of trees and diameter classes in an uneven-aged hardwood stand is a reversed J-shaped curve. The q-value is one mathematical expression of the shape of this curve. Quotients (q-value) can be calculated by dividing the number of trees in each DBH class by the number of trees in the next larger DBH class. The average of these quotients is the q-value for the stand.

quadratic mean diameter (**DBHq**). Diameter of the tree of average basal area calculated as follows:

$$DBHq = (1/N) * d_i^2$$

where

N = the number of trees sampled
d_i = the diameter at breast height (DBH) of tree i

R

radial check. A basal seam created by overgrowth of a persistent dead companion sprout (may represent a grading defect).

radicle (root). The seed contains a radicle or root meristem in the embryo from which the first tap root develops.

raptor. A bird of prey.

receptacle. The end of the flower stalk on which floral parts are borne.

Recovery Plan. A plan developed specifically for a species at risk with the primary goals being to ensure the species does not become extirpated in Canada and that population numbers increase sufficiently to allow for its recovery.

recruitment. Process of maintaining, restoring, or increasing the seedling and sapling component of a stand.

reforestation. The natural or artificial restocking of an area with forest trees.

regeneration. The renewal of a tree crop whether by natural or artificial means. Also the young crop itself which commonly is referred to as reproduction.

release. Freeing a tree or group of trees from competition by cutting or otherwise eliminating growth that is overtopping or closely surrounding them.

removal cut. One or more cuts in the shelterwood system that releases established seedlings. The last removal cut is called the final removal cut.

reproduction.
- The process by which a forest is renewed:
    - **artificial**: Renewal by direct sowing or planting.
    - **natural**: Renewal by self-sown seeds, sprouts, rhizomes, etc.
- Seedlings or saplings of any origin.

reproduction methods.
- **clearcutting**: Removal of the entire forest in one cut. This method perpetuates even-aged stands.
- **seed-tree**: Removal of the mature timber in one cut, except for a small number of seed trees; called a group cutting when the seed trees are left in groups, a reserve cutting when specifically selected seed trees are left for growth, as well as to furnish seed.
- **selection**: Removal of mature timber, usually the oldest or largest trees, either as single scattered trees or in small groups at relatively short intervals, commonly 15 to 25 years, repeated indefinitely. This encourages a continuous establishment of natural reproduction and an uneven-aged stand is maintained.
- **shelterwood**: Removal of the mature timber in a series of cuttings, which extend over a period of years. Usually equal to not more than one-quarter (often not more than one-tenth) of the time required to grow the crop. The establishment of natural reproduction under the partial shelter of seed trees is encouraged, but sometimes these areas must be artificially regenerated.
- **coppice**: Forest regeneration by sprouting (vegetative reproduction) from stumps or roots.

reserve. An area of forest land that, by law or policy, is not available for harvesting. Areas of land and water set aside for ecosystem protection, outdoor and tourism values, preservation of rare species, gene pool, wildlife protection etc.

residual basal area. The basal area per hectare of acceptable trees left standing after harvest.

residual stand. Trees, often of sawlog size, left in a stand after thinning to grow until the next harvest. Also called leave trees.

residuals (**residual trees**). Trees left standing after harvesting.

resource values. Products or commodities associated with forest lands and largely dependent on ecological processes. These include, but are not limited to, water quality and quantity, forage, fish, wildlife, timber, recreation, energy, minerals and cultural and heritage resources.

rhizome. A horizontal stem that bears roots and leafy shoots.

riparian zone. That area adjacent to rivers and streams identified by vegetation, wildlife and other qualities unique to these locations.

roots. The below-ground tree or plant parts that provide physical support, absorb water and nutrients from the soil and store food produced by photosynthesis.

root graft. A functional union of two roots after their formation, commonly between roots of the same individual, or, roots of neighboring trees, of the same species.

rotation. The period of years required to establish and grow a timber crop to a specified condition of maturity, when it may be harvested and a new tree crop started.

rotation age. The age at which a stand is considered ready for harvesting under an adopted plan of management.

rot. Wood in a state of decay.

S

salvage. To harvest trees that are dead or are in poor condition but can still yield a forest product.

samara. A dry, non-splitting, winged fruit, one- or two-seeded.

sample. A small collection from some larger population.

sample tree. A representative or average-size tree, chosen for detailed measurement of condition, size, growth, or quality.

sanitation cut. The removal of dead, damaged, or susceptible trees done primarily to prevent the spread of pests or pathogens and so promote forest hygiene.

sapling. A young tree of small diameter, typically 1 to 9 cm DBH.

sapwood. The light-coloured wood that appears on the outer portion of a cross section of a tree. Contains living cells; serves to conduct water and minerals to the crown.

savannah. A treed community with 11 to 35 % cover of coniferous or deciduous trees.

sawlog. A log large enough to be sawn into lumber.

sawtimber. Trees that yield logs suitable in size and quality for the production of lumber.

scale. The estimated sound volume of a log or group of logs in terms of a given log rule or formula; used to estimate the sound volume of a log or group of logs.

scarify. To disturb the forest floor and top soil in preparation for natural regeneration or direct seeding or planting.

scavenger rot. A sap rot or heart rot most prevalent on declining or dying trees.

second growth. A second forest that develops after harvest of the original, natural forest.

secondary cavity-user. Wildlife that use decay cavities or ones abandoned by primary excavators.

seedbank. The store of dormant seeds buried in the soil.

seedbed. The soil, forest floor or other media on which seed falls.

seed cutting. Removal of trees in a mature stand to effect permanent openings in the canopy (if not done in a preparatory cutting) and thereby provide conditions for securing regeneration from the seed of trees retained for this purpose. Also the first of the shelterwood cuttings.

seed tree.
- A tree that produces seed.
- Trees reserved in a harvest operation to supply seed.

seed year. A year in which a given species produces a seed crop greatly in excess of the normal. Applied usually to trees of irregular or infrequent seed production.

seed zone. Areas of similar climatic and elevation conditions, used to specify where tree seed was collected and where trees from such seed are most likely to be successfully grown.

seedbed. In natural plant reproduction, the soil or forest floor on which seed falls; in nursery practice, a prepared area in which seed is sown.

seeding. A reforestation method by sowing seeds, aerially or by hand. Often done immediately after harvest so that a new forest is started the next growing season.

seedling. A small tree grown from seed. Usually the term is restricted to trees equal to or less than 1 cm DBH.

seep. A spot where water contained in the ground oozes slowly to the surface and often forms a pool. A small spring.

selection silvicultural system. A periodic partial-cutting, controlled by basal area, using vigor and risk characteristics to determine individual tree selection. An uneven-aged silvicultural system.

selective cutting. The cutting of individual selected trees. There are generally few if any control measures. Also known as high-grading. Not to be confused with the selection silvicultural system.

self-pruning. The natural death and fall of branches from live trees due to causes such as light and food deficiencies, decay, insect attack, snow and ice; also called natural pruning.

senescence. The process of turnover of green biomass into yellow (or dead) biomass Senescence mainly depends on origin and development of a plant, but it is also influenced by dryness and/or nutrient stress and pest diseases.

serotiny. Refers to cones that remain closed on the tree for one or more years and may open by exposure to temperature $\leq 50^{o}C$.

shade tolerance. The capacity of a tree or plant species to develop and grow in the shade of and in competition with other trees or plants.

shake.

- A lengthwise separation of wood (usually caused by wind) that usually occurs between and parallel to the growth layers.
- A thin section split from a bolt of wood and used for roofing or siding.

shelterwood. The cutting method that describes the silvicultural system in which, in order to provide a source of seed and/or protection for regeneration, the old crop (the shelterwood) is removed in two or more successive shelterwood cuttings. The first cutting is ordinarily the seed cutting, though it may be preceded by a preparatory cutting and the last is the final cutting. Any intervening cutting is termed removal cutting. An even-aged stand results.

shelterwood silvicultural system. An even-aged silvicultural system where in order to provide a source of seed and/or protection for regeneration, the old crop is removed in two or more successive cuttings:

- **Group Shelterwood System**: Patches of advanced regeneration arising from thinnings or from natural disturbances, commonly developed in even-aged stands. Where this condition is prominent, shelterwood cuttings can be made specifically in relation to the requirements of each group of advanced regeneration. These clumps of regeneration are enlarged by the removal of all or most of the trees above them and initiating preparatory or seeding cuttings around them. The holes created in the canopy are gradually enlarged to keep pace with the establishment of reproduction.
- **Irregular Shelterwood System**: Harvest cutting in which opening of canopy is irregular and gradual; generally in groups, with the final cutting often is strips; regeneration natural; regeneration interval long, often up to half the rotation and the resultant crop

considerably uneven-aged and irregular.

- **Strip Shelterwood System**: A shelterwood system in which regeneration cuttings are carried out on fairly wide strips, generally against the prevailing winds and progress rapidly; regeneration is mainly natural, regeneration interval short and resultant crop fairly even-aged and regular.
- **Uniform Shelterwood System**: A shelterwood system in which the canopy is opened fairly evenly throughout the regeneration area; regeneration is mainly natural, though it may be supplemented artificially; regeneration interval fairly short and resultant crop more or less even-aged and regular.

shrub. A woody perennial plant (lives more than one year) that differs from a perennial herb by its woody, persistent stems and from a tree by its low stature and branches that start from the base.

significant wildlife habitat. Wildlife habitats that are ecologically important in terms of features, functions, representation or amount, and their contribution to the quality and diversity of an area.

silvics. A knowledge of the nature of forests and forest trees, how they grow, reproduce and respond to changes in their environment.

silvicultural system. A process whereby forests are tended, harvested and replaced, resulting in a forest of distinctive form. Systems are classified according to the method of carrying out the fellings that remove the mature crop with a view to regeneration and according to the type of forest thereby produced.

silviculture. The art and science of producing and tending a forest; the theory and practice of controlling forest establishment, composition, growth and quality of forests to achieve the objectives of management.

silviculture prescription. A site-specific operational plan that describes the forest management objectives for an area. It prescribes the methods for harvesting the existing forest stand and a series of silviculture treatments that will be carried out to establish a free growing stand in a manner that accommodates other resource values as identified.

single-tree selection. The cutting method that describes the silvicultural system in which trees are removed individually, here and there, each year over an entire forest or stand. The resultant stand usually regenerates naturally and becomes all-aged. ***see*** *selection silvicultural system.*

site. An area of land, especially with reference to its capacity to produce vegetation as a function of environmental factors (climate, soil, biology, etc.).

site class. A grouping of similar site indexes that indicates relative productivity. The common system in Ontario is Site Class X, 1, 2, 3, 4 (PFR).

Site District. A subdivision of a Site Region that is based on a characteristic pattern of physiographic features that distinguish fairly large areas from each other (Hills 1959).

site form. A numerical expression of forest site quality based on the height in meters (m), at a specified diameter (DBH) of dominant and codominant trees in a stand. Used for uneven-aged stands.

site index. A numerical expression of forest site quality based on the height in meters (m), at a specified age (usually age 50 years), of dominant and codominant trees in a stand. Used for even-aged stands.

site preparation. Any treatment of a forest site to prepare it for establishment of a plantation or for natural regeneration.

Site Region. Hills (1959) divided Ontario into Site Regions that are considered to be areas of similar potential biological production, based on climate as modified by physiographic landform and proximity to the Great Lakes.

skid road (**skid trail**). A pathway over which logs are dragged (skidded) from the stump to the landing. Logs are dragged by a machine called a skidder or by horses.

skidder. A wheeled or tracked vehicle used for sliding and dragging logs from the stump to a landing.

skidding. The process of dragging logs from the woods to a landing.

slash.

- Tree tops, branches, bark and other debris, left after a forest operation; or
- The process of cutting down undesirable vegetation.

snag. A standing, dead tree or a standing section of the stem of a tree broken off at the height of six meters or more. If less than six meters, it is properly termed a stub.

softwood. One of the botanical group of trees that generally have needle or scale-like leaves-the conifers. Also the wood produced by such trees, regardless of texture or density.

soil. Unconsolidated mineral material or organic material that is greater than 15 cm thick that occurs at the earth's surface, has undergone soil formation processes, usually exhibits a distinct soil profile and is capable of supporting plant growth.

soil horizon. A layer of soil with distinct characteristics that separate it from other soil layers.

soil moisture. The relative amount of water in the soil; usually applied to upper levels of soil, occasionally to humus layer.

soil profile. A vertical section of soil showing the nature and thickness of the various horizons, often used in soil classification.

soil series. Grouping of soils with similar profile characteristics.

soil texture. The relative proportion of various particle sizes such as sand, silt, clay and coarser materials in a mineral soil sample. The Canadian System of Soil Classification describes the basic textural classes (clay, silty clay, sandy loam, *etc.*)

spacing.

- The distance between trees in a plantation, a thinned stand, or a natural stand.
- The removal of undesirable trees within a young stand to control stocking, to maintain or improve growth, to increase wood quality and value, or to achieve other resource management objectives.

species of conservation concern. Includes endangered, threatened, vulnerable (or rare) plant or animal species as well as plant or animal species currently experiencing significant population declines in the province, or plant or animal species of particular importance to the Province or to a local region for any number of reasons.

species (of trees). Trees having very similar genetic makeup, so that they freely interbreed and have common characteristics. In common language, a 'kind' or 'variety.' Each species is identified by a scientific name that consists of a genus portion and then a species portion (*Pinus strobus*, white pine).

species composition. The percentage of each recognized tree species comprising the forest type based upon the gross volume, the relative number of stems per hectare or basal area.

spikelet. An elongated inflorescence, consisting of one or more flowers.

spike top. A tree with a dead top, usually a mark of declining vigor.

sporangium. An organ in which spores are produced.

spore. A one-celled asexual reproductive organ. Almost exclusively associate with non-flowering plants (e.g. mosses, fungi).

sprout.

- Any shoot arising from a plant; or
- A young tree developed directly from the base, stump, or root of another tree. Relatively common among hardwoods.

stand. An aggregation of trees occupying a specific area and uniform enough in composition (species), age and arrangement to be distinguishable from the forest on adjoining areas.

stand density. The number of trees usually expressed on a per hectare basis.

stand structure. The distribution and representation of age and/or size classes and of crown and other tree classes within a stand.

stand table. A summary table showing the number of trees per unit area by species and diameter classes, for a stand or type. The data may also be presented in the form of a frequency distribution of diameter classes.

stem. The trunk of a tree.

stick nest. A platform of sticks (twigs up to small branches) constructed by some bird species for nesting.

stocking.

- A qualitative expression of the adequacy of tree cover on an area, in relation to a pre-established norm, expressed in terms of crown closure, number of trees, basal area, or volume.
    - **fully stocked**: Productive forest land stocked with trees of a merchantable species. These trees, by number and distribution or by average DBH, basal area, or volume, are such that at rotation age they will produce a timber stand that occupies the potentially productive ground. The stocking , number of trees, and, distribution required to achieve this will usually be determined from yield curves. Sometimes called *normally stocked*.
    - **over stocked**: Productive forest land stocked with more trees of merchantable species than normal or full stocking would require. Growth is in some respect retarded and the full number of trees will not reach rotation age according to an appropriate yield and stock tables for the particular site and species.

stock table. A summary table showing the volume of trees per unit area by species and diameter classes, for a stand or type.

stolon. An elongate stem developing along the surface of the ground that takes root and forms new plants at the nodes or apex.

stone. A part of a drupe; consisting of a seed enclosed in a hard bony endocarp.

stratification. A pre-germinative treatment to break dormancy in seeds accomplished by exposing imbibed seeds to cold (2 to 5^{o}C) or warm conditions.

stream. A permanent or intermittent water course.

stub. A standing, dead tree or a standing section of the stem of a tree broken off at the height of six meters or less. If more than six meters, it is properly termed a snag.

stumpage. The value of timber as it stands uncut in the woods; in a general sense, the standing timber itself. Can also denote price paid for this timber.

succession. The replacement of one plant community by another in progressive development towards climax vegetation.

- *types of succession*:
    - **primary**: Plant succession on newly formed soils or surfaces, exposed for the first time, that have never borne vegetation.
    - **secondary**: Plant succession following the destruction of a part or all of the original vegetation.

sucker.

- A sprout from the lower portion of a stem, especially from the root.
- A shoot or tree originating from adventitious buds on roots.

sunscald. Death of cambial tissue on one side of a tree, caused by exposure to direct sunlight.

supercanopy tree. A living tree that sticks up well above the main canopy of a forest stand.

suppressed tree. *see overtopped*.

sustainability. The concept of producing a biological resource under management practices that ensure replacement of the part harvested, by re-growth or reproduction, before another harvest occurs.

sustainable forest management. Management regimes applied to forest land which maintain the productive and renewal capacities as well as the genetic, species and ecological diversity of forest ecosystems.

sustained yield. A policy, method, or plan of forest management that calls for continuous production, to achieve, at the earliest practicable time, an approximate balance between net growth and amount harvested.

swamp. A mineral-rich wetland characterized by a cover of deciduous or coniferous trees.

sweep. A gradual, but pronounced, bend in a log, pole, or piling; considered a defect.

T

tally. The count of trees, logs, or other products; to count trees, logs, or other products; to record products, distances, etc. as measured.

talus. Refers to fragmented rock, which has broken away from bedrock surfaces and fallen to the base of the bedrock feature where it accumulates to form a sloping broken rock surface.

taper. The gradual reduction of diameter in a stem of a tree or a log from the base to the top.

tending. Generally, any operation carried out for the benefit of a forest crop at any stage of its life, e.g., cleaning, thinning, pruning.

terrestrial system. Upland areas, where the water table is normally below the soil surface.

thinning. Cutting in an immature stand to increase the growth rate of the leave trees. The goal is to foster quality growth, improve composition, promote sanitation and recover and use material that would otherwise be lost to mortality. Thinning does not generally increase per-hectare volume growth, but it can increase lumber yield.

thinning from above. A thinning that favors the most promising (not necessarily the dominant) stems, with due regard to even distribution over the stand, by removing those trees that interfere with them. Also known as *crown thinning*.

thinning from below. A thinning that favors the dominants or selected dominants more or less evenly distributed over the stand by removing a varying proportion of the other trees. Also known as *low thinning*.

- *types of thinning*:
    - **low thinning**: The removal of trees from the lower crown classes in a stand. Also known as *thinning from below*.
    - **crown thinning**: The removal of trees from the middle and upper crown classes in a stand, to favor the most promising trees of these classes. Also known as *thinning from above*.
    - **selection thinning**: Removal of dominant trees to benefit trees in lower crown classes.
    - **free thinning**: Removal of trees to benefit best trees, regardless of crown class.
    - **mechanical thinning**: Removal of trees based totally on their spacing or arrangement. Also known as *row thinning*.

till. Glacial deposits laid down directly by the ice with little or no transportation or sorting by water.

timber. A term loosely applied to forest stands or their products; often applied to wood in forms suitable for heavy construction.

tolerance. The capacity of a tree or plant to develop and grow in the shade of (and in competition with) other trees or plants; a general term for the relative ability of a species to survive a deficiency of an essential growth requirement (light, moisture, nutrient supply).

top height. The mean height of 100 trees per hectare of largest diameter at breast height.

tree. A woody plant having one well-defined stem and a more or less definitely formed crown, usually attaining a height of at least three meters.

tree age. The number of years since the germination of the seed, or the budding of the sprout or root sucker.

tree length. Entire length of tree, or with the top lopped off at small diameter, as in skidding tree length to a landing for bucking into logs.

tree marking. Selecting and marking trees to be harvested and trees to be left to grow. Selected trees are usually identified with coloured paint on the tree trunk at DBH and at the stump. Normal colours used in Ontario are: orange/yellow for stem removal and blue for residual stems.

U

UGS - *unacceptable growing stock*. These trees have a high risk of dying and are expected to decline over the next cutting cycle. They include trees that are of poor form and/or low quality.

underbrush. The brush growing in a forest.

undergrowth. Small trees and shrubs and other plants growing under a forest canopy.

understory. That portion of the trees or other vegetation in a forest stand below the canopy.

uneven-aged. Applied to a stand in which there are considerable differences in the age of the trees and in which three or more age classes are represented.

uneven-aged management. The application of a combination of actions needed to simultaneously maintain continuous high-forest cover, recurring regeneration of desirable species and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single tree selection and group selection.

unmerchantable. A tree or stand that has not attained sufficient size, quality and/or volume to make it suitable for harvesting.

V

value-limiting defect. Such features are considered to be either:

- **Scaleable Defect**: such as rot or shake, that reduce sound useable volume or durability; or
- **Grade Defect**: such as knots or stain, that reduce strength or utility.

vegetation type. The sixth and finest level of resolution in the Ecological Land Classification system. It represents recurring vegetation patterns observed on the landscape, based only on plant species composition. Normally, "Vegetation Types" include the names of dominant plant species of the community, based on relative abundance.

vegetative reproduction. Reproduction by a root, stem, leaf, or some other primary vegetative part of a plant body.

volume. The amount of wood in a tree, stand, or, other specified area according to some unit of measurement or some standard of use (e.g. m^3 or m^3/ha)

- **Gross Total Volume (GTV)**: Volume of the main stem, including stump and top, as well as, defective and decayed wood of individual trees or stands.
- **Gross Merchantable Volume (GMV)**: Volume of the main stem, excluding a specified stump and top, but, including defective and decayed wood of individual trees or stands.
- **Net Merchantable Volume (NMV)**: Volume of the main stem, excluding stump and top, as well as, decayed wood of individual trees or stands.

volume table. A table showing gross volume of trees, based on given tree measurements (usually DBH and height).

W

water table. The upper surface of the water saturation zone.

wetland. Land that is seasonally or permanently covered by shallow water, or land where the water table is close to or at the surface. In either case, the presence of abundant water has caused the formation of hydric soils and has favored the dominance of either hydrophytic or water-tolerant plants.

wetland system. Areas where water levels fluctuate and are under two meters in depth.

wildlife. All wild mammals, birds, reptiles, amphibians, fishes, invertebrates, plants, fungi, algae, bacteria and other wild organisms.

windfall. A tree uprooted or broken off by wind; an area on which the trees have been thrown by wind. ***see*** *windthrow*.

windfirm. Descriptive of trees and plantations that, because of species, soil or relative exposure, are unlikely to suffer windthrow.

windthrow. Uprooting or breakage of trees caused by strong winds.

witches'-broom. An abnormal tufted growth of small branches on a tree or shrub caused by fungi or viruses.

wood. The lignified water-conducting, supporting and storage tissue of branches, stems and roots.

X

xylem. A complex tissue in the vascular system of higher plants that consists of vessels, tracheids, or both together with wood fibers and parenchyma cells, functions chiefly in conduction but also in support and storage and typically constitutes the woody element.

xeric. Describes a dry site.

Y

yield. Growth or increment accumulated by trees at specified ages expressed by volume or weight to defined merchantability standards.

yield curve. A graphical or mathematical representation of the yield of a given species, on a given site, at a given time.

yield table. A summary table for stands (usually even-aged stands) of one or more species on different site qualities, showing characteristics at different ages. The stand characteristics usually include average diameter and height and total basal area, number of trees and volume per hectare.

- Empirical: Prepared for actual average stand conditions.
- Normal: Prepared for normally stocked stands.
- Variable Density: Prepared for stands of varying density expressed as numbers of trees per hectare.

young growth. Any forest of relatively young age and condition.