Ontario

# Silvicultural Guide to Managing for Black Spruce, Jack Pine, and Aspen on Boreal Forest Ecosites in Ontario

## Book I: Silviculture in Ontario

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## MNR’s Strategic Directions and its 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, the Ministry of Natural Resources is steward of provincial parks, natural heritage areas, forests, fisheries, wildlife, mineral aggregates, fuel minerals, and Crown lands and waters which make up 87 percent of Ontario.

In 1991, the Ministry of Natural Resources released a document MNR: Direction ’90s which outlines the goal and objectives for the Ministry, which are based on the concept of sustainable development, as expressed by the World Commission on Environment and Development. Within MNR, policy and program development take their lead from Direction ’90s. Those strategic directions are also considered in Ministry land use and resource management planning.

More recently, in 1994, the Ministry of Natural Resources finalized its Statement of Environmental Values (SEV) under the Environmental Bill of Rights. The Statement of Environmental Values is a document which describes how the purposes of the Environmental Bill of Rights (EBR) are to be considered whenever decisions that might significantly affect the environment are made in the Ministry.

The Ministry’s SEV is based on MNR: Direction ’90s. The Ministry has taken this approach to its SEV because the strategic direction outlined in MNR: Direction ’90s reflect the purposes of the EBR.

During the development of this silvicultural guide, the Ministry has considered both MNR: Direction ’90s 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.

# FOREWORD

## Silvicultural Guides

This is the Silvicultural Guide for Boreal Forest Ecosites in Ontario. This guide replaces *A Silvicultural Guide to the Spruce Working Group in Ontario* (Arnup *et al.* 1988), *Jack Pine Working Group* (OMNR 1986), and *A Silvicultural Guide to the Poplar Working Group in Ontario* (Davison *et al.* 1988).

The project to review, revise and rewrite the silvicultural guides grew out of a legal requirement stated in Term and Condition 94 (T&C 94) of the class environmental assessment for timber management on Crown lands in Ontario (MOEE 1994). T&C 94 states that "all existing silvicultural guides shall be reviewed to ensure that they reflect current scientific knowledge as it applies to Ontario, and to provide descriptions of general standard site types for use in developing silvicultural ground rules in timber management plans."

**General standard site types, as defined in the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996), are synonymous with ecosites and site types, the working units of forest ecosystem classification (FEC) systems.**

The *Silvicultural Guide to Managing for Black Spruce, Jack Pine, and Aspen on Boreal Forest Ecosites in Ontario* provides silvicultural information within the context of forest ecosystems. This represents a significant change from the working group (crop species) approach used in the earlier silvicultural guides.

## Guideline Revision

Ecosystems and our understanding of them are never static. As science, knowledge and experience add to our understanding of boreal forest ecosystems, this guide will continue to evolve. It is a work in progress that we will revise, improve and update so that it continues to reflect current knowledge and experience, while providing us with the tools to adapt to the challenges that lie ahead.

# Table of Contents

# ACKNOWLEDGMENTS

This silvicultural guide was designed and built by an integrated team from MNR's Northeast Science & Technology (NEST) unit in Timmins, and Northwest Science & Technology (NWST) unit in Thunder Bay.

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Many resource management staff from forest companies and MNR helped in developing and reviewing the ecological and silvicultural interpretations in the guide. We would like to extend thanks to the following people for their input and comments:

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This guide is presented
in memory of Neil Maurer,
a dedicated forester
who was very much at
home in Boreal Ontario,
and who believed very
strongly in the application
of science to make forest
practices better.

# About this Guide

This guide provides silvicultural and ecological information for the management of black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.) and aspen (*Populus tremuloides* Michx., *Populus grandidentata* Michx.), within the context of sustainable forest management.

Our intention in developing this silvicultural guide is to provide:

- a reference tool for developing forest units and silvicultural ground rules
- an overview of current boreal silvicultural science and knowledge in Ontario
- a repository for silvicultural experience in Ontario's boreal forest
- a training and educational tool.

This guide is one of several publications associated with the Forest Management Planning Manual (OMNR 1996), which is a regulating document under the Crown Forest Sustainability Act (CFSA 1994). This guide specifically identifies silvicultural practices (required in silvicultural ground rules) within the ecological framework provided by general standard site types.

This guide is not intended to be the sole source of silvicultural information, or a substitute for local knowledge and experience. It is also not intended to constrain the application of sound silvicultural practices. It provides a framework and a context for generating, collecting, validating and applying local knowledge and experience in the Boreal Forest of Ontario. For more information on the science of silviculture in Ontario, see *Regenerating Ontario's Forests* (Columbo and Wagner in prep.).

## How this Guide is Organized

This guide includes three books. Book I: Siviculture in Ontario (this book), includes:

**Section I.** **Introduction**, presents the legislative, philosophical, and ecological context in which the guide was developed.

**Section II.** **Silvicultural Practices**, provides an overview of the science, art and practice of silviculture in Ontario's boreal forest. This also section attempts to rationalize and present a standard set of silvicultural terms for use in the forest management planning process.

**Section III.** **Autecology of Selected Forest Plants**, provides information about the response and adaptation of selected crop trees and competitor species to the physical environment, disturbance, and management intervention.

**Section IV.** **Silvicultural Decision Tools**, presents a catalogue and short description of decision-support tools available for boreal Ontario.

**Section V.** **Applying this Guide**, demonstrates how to use the guide to build forest units, silvicultural ground rules and silvicultural treatment packages.

Book II: Ecological and Management Interpretations for Northwest Ecosites, includes:

**Section I.** **The Ecological Framework** introduces and explains the ecological and management interpretations in Section II, the terms and graphical conventions used, how the interpretations were derived, the limitations to their application, and data sources.

**Section II.** **Ecological and Management Interpretations** delivers a suite of ecological and silvicultural information, within the framework of general standard site types, as defined by the Terrestrial and Wetland Ecosites of Northwestern Ontario (Racey *et al.* 1996).

Book III: Ecological and Management Interpretations for Northeast Site Types, includes:

**Section I.** **The Ecological Framework** introduces and explains the ecological and management interpretations in Section II, the terms and graphical conventions used, how the interpretations were derived, the limitations to their application, and data sources. This section also includes a comparative cross-reference of selected Central Ecosites and Northeast FEC Site Types.

**Section II.** **Ecological and Management Interpretations** delivers a suite of ecological and silvicultural information, within the framework of general standard site types, as defined by the Forest Ecosystem Classification for Northeastern Ontario (McCarthy *et al.* 1994).

# *Section I*
## Introduction

## Policy Framework for Sustainable Forests

The overall context for forest management in Ontario is the *Policy Framework for Sustainable Forests* (OMNR 1995a). This framework states that the goal for Ontario's forests is:

*...to ensure the long-term health of our forest ecosystems for the benefit of the local and global environments, while enabling present and future generations to meet their material and social needs.*

Sustaining forests is fundamental to sustaining development based on forests. This principle and the legislative authority for this framework is found in the Crown Forest Sustainability Act (CFSA 1994).

The CFSA defines sustainability as long-term Crown forest health. The Act defines forest health as the condition of a forest ecosystem that sustains the ecosystem's complexity while providing for the needs of the people of Ontario.

Ontario's approach to achieving sustainability is to define desired future forest conditions and then take actions compatible with achieving these conditions. Developing and applying silvicultural practices that emulate natural disturbances and landscape patterns is an important element in Ontario's management strategy.

In a managed forest, we can achieve desired future forest conditions by building on our understanding of forest ecosystems and applying management practices consistent with that understanding. This silvicultural guide provides some of the tools to make that possible.

For related information and operational direction see the *Forest Information Manual* (OMNR 1995b) and *Forest Operations and Silviculture Manual* (OMNR 1995c).

## An Ecological Approach to Forest Management

In the policy statement *Direction '90s* (OMNR 1991a) the Ontario Ministry of Natural Resources embraced sustainable development as the cornerstone of its new direction. The policy statement calls for an ecosystem-based (ecological) approach to the management of Ontario's natural resources. Adopting an ecological approach to management involves a change from an emphasis on resource extraction to an emphasis on ecosystem health.

This new focus on maintaining sustainable healthy ecosystems requires an understanding of the variability among living organisms and the ecological complexes in which they occur (biodiversity). One way of looking at biodiversity is through ecosystem composition, structure and function, over different spatial scales.

Noss (1990) provides a simple framework (**Table 1**) for identifying the critical components of biodiversity in forest management.

Forest management planning influences stand composition and structure largely through the silviculture treatments prescribed in the silvicultural ground rules and forest operation prescriptions. Ground rules and silvicultural treatment packages are developed to meet management objectives, based on a knowledge and understanding of specific stand and site attributes.

Silvicultural strategies (ground rules) seek to achieve desired future forest conditions while sustaining ecosystem health. The most efficient and effective silvicultural treatments are often innovative applications of intervention that come from an intimate understanding of the prevailing natural processes on a site.

Forest ecosystem site types or ecosites must form the basis for both ground rules and prescriptions. Ecosites (site types) are:

> *"...an essential framework for silvicultural practice, if mistakes are to be avoided and feedback from successes and failures is to be understood and explained"* (NRC 1995).

Table 1. A framework for identifying critical components of biological diversity in forest management (adapted from Noss 1990). The shaded area represents examples of components that are directly manipulated by forest management and hence are most readily accounted for in management plans.

<table>
<tr><th></th><th>Composition</th><th>Structure</th><th>Function</th></tr>
<tr><td rowspan="2">Landscape (Forest)</td><td>area of each forest type<br><br>age class distribution</td><td>size, shape, and spacing of patches<br><br>corridors</td><td rowspan="2">fire and insect spread<br><br>habitat and wood supply</td></tr>
<tr><td colspan="2">Area Selected for Harvest</td></tr>
<tr><td rowspan="2">Site (Stand)</td><td>species composition - all layers</td><td>snags, coarse woody debris, super-canopy trees, multi-storied canopies</td><td rowspan="2">habitat suitability, nutrient cycling</td></tr>
<tr><td colspan="2">Silvicultural Ground Rules</td></tr>
<tr><td>Population</td><td>relative abundance/biomass of species</td><td>age/sex ratios</td><td>fertility, recruitment, mortality rates</td></tr>
<tr><td>Gene</td><td>number of different alleles, presence of rare alleles</td><td>effective population size, heritability, overlap</td><td>inbreeding depression, genetic drift, mutation rates</td></tr>
</table>

# GENERAL STANDARD SITE TYPES

The 1986-88 silvicultural guides (OMNR 1986, Arnup *et al.* 1988, Davidson *et al.* 1988) were based on scientific literature, expert opinion and operational experience, and were presented as individual and independent working groups (crop species). This guide is a text and diagrammatic presentation of interpretive silvicultural information for black spruce, jack pine and aspen. Information and interpretations are based on scientific literature, expert opinion, and operational experience, organized and presented by general standard site type (GSST).

GSST is synonymous with ecosite and site type. It is a coding or labelling system for referencing site description information on similar sites across the province. The two FEC systems employed in Ontario's boreal forest are the Terrestrial and Wetland Ecosites of Northwestern Ontario (Racey *et al.* 1996) and Forest Ecosystems of Northeastern Ontario (McCarthy *et al.* 1994). A third FEC system, Forest Ecosystems of Central Ontario (Chambers *et al.* 1997) can be applied in the transition zones between the Great Lakes-St. Lawrence and the Boreal Forest Regions (Rowe 1972).

Site-specific management is not a new concept. Hills (1952a) defined a total site as "the combination of biotic, climatic and soil conditions of an area," or "an area considered as to its ecological factors with reference to capacity to produce forests or other vegetation." Selection of crop and management practices would consider:

- the best adjustment of crop to total site considering combinations of crops, treatments and physiographic features, and
- the best combination of crop and management with physiographic site which will fit in with probable production, marketing and other economic-social conditions existing during the growth and harvesting of the crop (Hills 1952b).

Forest production varies on the same soil with variations in climate. The concept of site was placed in a broader ecological context by Hills (1960) with the description of site regions and site districts, which have been adopted as ecoregions for Ontario.

Burger and Pierpoint (1990) describe the evolution of site classification to forest ecosystem classification (FEC) as focused on silvicultural applications. These FECs (Jones *et al.* 1983, Merchant *et al.* 1989, Sims *et al.* 1997) provided an opportunity to develop silvicultural and wildlife interpretations for site-specific management (Pierpoint *et al.* 1984, Merchant *et al.* 1989, Racey *et al.* 1997 reprinted). Since then, there have been descriptions of site types for northeastern Ontario (McCarthy *et al.* 1994) terrestrial and wetland ecosites for northwestern Ontario (Racey *et al.* 1996) and forested ecosites in central Ontario (Chambers *et al.* 1997). These site classifications form the basis for the interpretations in this silvicultural guide.

The Forest Management Planning Manual for Ontario's Crown Forests (OMNR 1996) requires that ecosites (site types) be used as building blocks in the description of forest units, in the development of silvicultural ground rules, and in reporting forest operations prescriptions within annual work schedules. Ecosites or site types are appropriate tools for describing the productive forest land base and for use in other forest management planning applications.

Forest ecosystems are complex interactions among species and environmental conditions. FEC simplifies this complexity so that pattern and commonalities can be recognized and applied at a practical management level. No classification system can encompass all of the complexity and diversity in the landscape. Users are bound to encounter sites that do not appear to fit a classification. **Forest ecosystem classification can only help managers develop prescriptions.**

Ecosites and site types are defined in terms of abiotic (soil depth, texture, moisture regime, hydrology and nutrient regime) and biotic (plant community structure and composition) factors. These factors are particularly relevant for understanding forest tree and stand dynamics. As such, the ecosite or site type has direct relevance for silviculture, forest productivity, successional studies, forest and landscape level planning, wetland evaluation and the description of major components of wildlife habitat. Silvicultural considerations that may be interpreted directly or indirectly from ecosites or site types include: tree growth and yield, vigor of competing species, ingress of naturals, advance growth and site hazard potential such as rutting and compaction.

Forested ecosites and site types are relatively stable land units. Soil depth, texture, moisture regime and general humus form are maintained through the majority of a forest rotation, and many attributes persist after harvest of the forest stand. Seed bank, nutrient capital and vegetative propagules are the legacy inherited from the previous stand. This legacy influences ecosite and site type function as the new plant community begins to modify the developing forest floor. The major factor affecting forest floor development is the structure and composition of the forest overstorey, and their influence on litter fall, sunlight penetration and precipitation throughfall. Consideration of both the biotic and abiotic aspects of the ecosite or site type and the biotic legacy remaining after harvest is essential to effective silviculture.

Ecosites and site types are part of an ecological land classification framework (**Table 2**) that also includes ecoelements, referred to as vegetation types (V-types) and soil types (S-types). Depending on the degree of resolution required, land units are described using ecosites (site types) and/or ecoelements. Ecoelements are only directly applicable to relatively small units of land, similar in size to plots within which the data were collected.

Table 2. Ecological land classification scales, recommended products and applications for boreal Ontario

| Classification Unit | Appropriate Scale[1] | Recommended Products | Example of Management Applications |
|---|---|---|---|
| Ecozone | 1:3,000,000 ($10^4$ - $10^6$ $km^2$) | Wilken (1986) | ecological context for Ontario |
| Ecoprovince | 1:1,000,000 ($10^4$ $km^2$) | Wilken (1986) | ecological context for Ontario |
| Ecoregion | 1:500,000 ($10^3$ - $10^4$ $km^2$) | Hill's site regions of Ontario (Hills 1961, Burger 1993) | strategic planning at regional or sub-regional level |
| Ecodistrict | 1:250,000 - 1:1,000,000 ($10^2$ - $10^4$ $km^2$) | Hill's site districts (Hills 1966) | strategic planning at regional or sub-regional level |
| Ecosection | 1:100,000 - 1:250,000 ($10^3$ - $10^4$ ha) | Ontario Land Inventory (OMNR 1977), Northern Ontario Engineering Geology Terrain Study (Gartner *et al.* 1981) | major landform contributions for forest prime land, broad habitat trends, water-shed evaluation |
| Ecosite | 1:10,000 - 1:20,000 (10 - $10^2$ ha) | Terrestrial and Wetland Ecosites of Northwestern Ontario (Racey *et al.* 1996), Site Types of Northeastern Ontario (McCarthy *et al.* 1994) | silvicultural ground rules, forest stand productivity, wildlife habitat components, wetland evaluation |
| Ecoelement | 1:2,000 - 1:10,000 ($10^2$ - $10^5$ $m^2$) | Northwestern Ontario Forest Ecosystem Classification (Sims *et al.* 1997), Northwestern Ontario Wetland Ecosys-tem Classification (Harris *et al.* 1996), Forest Ecosystems of Northeast-ern Ontario (McCarthy *et al.* 1994) | stand and sub-stand level studies of succession, competition, forest productivity, habitat and soil/ vegetation interaction |

1 - Appropriate scales are first identified in terms of approximate cartographic scales and then described in terms of resolution (size of land units typically portrayed)

# *Section II*

## Silvicultural Practices

## Silviculture in Ontario

The foundation of silviculture is the autecology (silvics) and synecology of tree species. Autecology is the branch of ecology dealing with the study of the responses and adaptations of individual species or populations to their environment (Barbour *et al*. 1987). Synecology deals with living communities rather than individuals (Spurr and Barnes 1980). The term silvics applies to the principles of growth and development of tree species and the forest as a biological unit. Aird (1994) defines silvics as the study of the life history, requirements and general characteristics of forest trees and stands in relation to the environment.

Silviculture is the scientific, creative and practical use of silvics at the site level. In the Environmental Assessment Board document (OMOEE 1994) silviculture is defined as the art and science of cultivating forest crops. Baskerville (1985) defines silviculture as the theory and practice of controlling the establishment, composition, constitution and development of forest stands. Oliver and Larson (1990) define it more concisely as the manipulation of forest stands through timber harvest, forest renewal and maintenance of the new forest. The art of silviculture involves the development of creative alternatives to achieve desired objectives. Decisions about the harvest method and pattern, and about the kinds and levels of renewal and tending activities, all play a role in the design of the future forest (Willcocks *et al*. 1990). We apply our knowledge of silvics to help us make these decisions.

Forest management encompasses silviculture but also happens on a broader scale. Forest management is the manipulation of the forest on the landscape and across time.

## Why Do We Practice Silviculture?

We practice silviculture to contribute to the primary goal of every forest management plan: a healthy, sustainable forest ecosystem (OMNR 1996). Managing, maintaining and restoring healthy and diverse ecosystems is Ontario’s prime natural resource stewardship responsibility. To achieve this, we manipulate stand development on a site to contribute to a desired future forest condition. The desired future forest condition combines specific objectives including timber production, provision and maintenance of wildlife habitat, landscape diversity, recreational resources, genetic diversity, etc.

Silviculture gives us the tools to:

- Maintain or increase species and genetic diversity.
- Manage stand composition. Forest stand compositions can be restricted to those species that are most suited to the location from both an economic, social and ecological viewpoint. Rotations can be shortened or lengthened in conjunction with achieving other goals.
- Manage stand structure. Smith (1986) defines it as “forest architecture,” the art of silviculture. We design stands to meet management objectives.
- Provide wildlife habitat, including coarse woody debris, snags, cover, food, etc.

- Maintain site quality. The forest soil is the most critical resource used in silviculture (Smith 1986).
- Reduce the risk of losses by increasing stand and forest stability and resilience. Maintaining a healthy forest will reduce tree mortality from different biotic and abiotic factors.
- Restore degraded sites.
- Facilitate harvesting. There are long term benefits in planning for future as well as present harvests.

# Silvicultural Terms

Silvicultural practices develop in response to local or regional needs. Understandably, the terminology used to describe these practices tends to have local and regional variations. Our intent in this publication is to establish and use a suite of silvicultural terms that can be accepted, understood and applied in the Boreal Forest of Ontario. Whenever possible, in providing definitions for these terms, we have tried to be consistent with Ontario's forest management planning manual, *Silvicultural Terms in Canada* (NRC 1995), and other traditional silvicultural references.

# Silvicultural Systems and Harvest Methods

## What is a Silvicultural System?

A silvicultural system is a process following accepted silvicultural principles, whereby crops constituting a forest are tended, harvested and regenerated, resulting in the production of crops of distinctive form. Systems are classified according to the method of harvesting the mature stands with a view to regeneration, and according to the type of crop produced (OMNR 1996).

Smith (1986) describes a silvicultural system as a designed program of silvicultural treatments during the whole life of a stand for the purpose of controlling stand establishment, composition and growth. Silvicultural systems are divided into several categories in a hierarchical system and grouped, at the highest level, according to whether the intent is to promote an even-aged or an uneven-aged forest. *Even-aged systems generally create stands where the trees are approximately the same age, or one age class. However, in some cases, even-aged systems can result in two distinct age classes of tress when some older trees are left behind after harvesting.*

## Selecting a Silvicultural System

There are many factors that influence the selection of a silvicultural system including:

- silvics of the species of interest
- reproductive habits of competitive species
- wildlife requirements

- the stand's potential as determined by site and environmental factors
- hazards created by insects and disease
- the natural disturbance regime
- options for applying fire to reach management objectives
- environmental hazards, such as frost
- the size, age and vigor of the trees in the existing stand, and the overall condition of the stand as affected by past management or natural influences
- genetics
- aesthetics and recreational values
- social and cultural values
- management objectives/constraints

The final selection of a silvicultural system involves the analysis and consideration of all the factors that can potentially influence the ability to meet management objectives (Burns 1983).

There are three silvicultural systems used in Ontario (**Table 1**). The clearcut system is most commonly used for the regeneration of black spruce, jack pine and aspen.

Table 1. Summary of silvicultural systems and harvesting methods used in boreal Ontario and suitability of each system for jack pine, black spruce and aspen.

| Silvicultural System | Harvesting Method | Black Spruce | Jack Pine | Aspen |
|---|---|---|---|---|
| Clearcut | Conventional | x | x | x |
| | Strip/Block | x | | x |
| | Patch | x | | x |
| | Single seed-tree | | x | |
| | Group seed-tree | x | | |
| | HARP | x | | |
| Shelterwood | | | | |
| Selection | | | | |

# The Clearcut System

The clearcut system involves the regeneration of an even-aged stand in which new seedlings become established in fully exposed micro-environments. Regeneration can originate naturally or artificially (OMNR 1996).

The Boreal Forest is disturbance driven and dominated by species that are adapted to these environmental conditions. Fire, wind and insects often affect extensive areas of forest, initiating regeneration. These areas normally regenerate to even-aged stands. Clearcutting, involving a range of cutblock sizes, creates landscape patterns which can approximate those created by natural disturbances.

Recent practices involve leaving residual areas within harvest blocks (often called residual management). The objective is to mimic the level of variability in natural disturbance patterns on a landscape. However, at the stand level, clearcutting will not emulate the degree of downed woody debris or vertical snag structure remaining after wildfire. The nutrient dynamics will also differ.

With the clearcut system, most or all of the existing overstorey is removed in one operation. This ends one growth phase and begins another. Features of the clearcut system include:

- well-suited to the managing of species adapted to take advantage of major disturbances
- most silvicultural effort follows the harvest
- simple regulation of cut by area
- produces wide variations in site impacts and effects, depending on site conditions, vegetation, and the size, shape and relative position on the landscape to adjacent stands

An important factor affecting the success of this system is the number and distribution of residual trees. Clearcuts are not always "cut clear." Overstorey trees can be left on a site after a clearcut, sometimes referred to as a partial harvest. On partial harvests where only the species or individual trees of highest timber value are removed, the result is a stand of unmerchantable overstorey trees. If these remaining trees have the potential to interfere with the successful establishment and subsequent development of the new stand, then these stems must be treated (e.g. felled, girdled, treated with herbicide). Otherwise this stand will be considered to have been "high-graded." High-grading, a practice which does not sustain forest ecosystems, is in direct conflict with and contravention of Section 1 of the Crown Forest Sustainability Act.

## Harvest Methods

Harvest method is a term used to further define or modify a silvicultural system, specifically the harvesting component or technique. This term is a "before-and-after" reference that identifies the pattern of removal during harvest and the distribution of residual stems.

Careful logging around advance growth (CLAAG) is an operational practice that can be applied with any harvest method under the clearcut silvicultural system, where the objective is to remove the overstorey, protect understorey advance growth, and regenerate an even-aged stand. The resulting stand develops under full light conditions, generally with a reduced rotation length.

*If there is any piece of silvicultural knowledge about which foresters in eastern North America have or should have learned and given to the world, it is the importance of advance growth* (Smith 1990).

Several terms have been used to refer to CLAAG, including one cut shelterwood (Smith 1986), preservation of advance growth (Groot 1994), and careful logging. The term careful logging is inappropriate because it also applies to operations that do not have advance growth preservation as an objective (Groot 1994).

The principles of CLAAG are to restrict equipment to repeatedly used trails and to space these trails as widely as possible. Harvesting in winter or with high flotation equipment in summer is preferable (Groot 1987, Archibald and Arnup 1993).

NOTE: Regeneration is not always of the same species as the overstorey. On some sites, CLAAG can increase the proportion of balsam fir in the future stand. Balsam fir advance growth success can be reduced with full-tree logging in the summer (Outcalt and White 1981).

Harvest methods typically used with the clearcut system are:

**Conventional** - The removal of a stand (or a number of adjacent stands) from a large contiguous area in one operation. In contrast to strip, patch or block harvest methods, this harvest method is not defined by the cutting cycle associated with adjacent uncut areas.

A variation of the conventional clearcut method is two stage removal. The principle behind this technique is the careful removal of the entire overstorey leaving all stems in the intermediate crown class for the final cut. The residual stand must be even-aged and fully occupy the site immediately following harvest. This harvest method was originally developed for mixedwood stands in Alberta and Saskatchewan (Wedeles *et al.* 1995). In boreal Ontario, this harvest method may have potential where stands exhibit a defined vertical structure, such as:

- stands with an aspen overstorey and a softwood understorey (often with white spruce)
- jack pine stands with an understorey of black spruce

This harvest method:

- can increase harvesting costs in the first cut and requires greater skill in cutting the stand
- can result in a balsam fir-dominated stand of lower future timber value, and higher fire and budworm hazard if understorey has a high fir component

- may result in widespread windthrow of the released intermediate trees
- can dramatically increase yield over a normal technical rotation (Hole 1993)
- can be more aesthetically acceptable than conventional clearcut

**Strip and Block** - The removal of the stand in progressive strips or blocks in more than one operation. Strip and block harvest methods are prescribed to encourage natural regeneration, provide wildlife habitat, protect fragile sites (NRC 1995), or for aesthetics.

Strip and block cutting are suitable regeneration options for black spruce stands because of large continuous seed supply, ready seed dispersal, elimination of establishment costs associated with artificial regeneration, and preservation of genetic diversity. When strip cutting for black spruce, strip widths of 10 to 30 m are appropriate for the driest and most sensitive shallow sites. For less sensitive shallow sites and deeper mineral soils, use strip widths of 40 to 60 m. For moist mineral soils and wet organic soils, use strip widths of 70 to 100 m (Haavisto 1975). Black spruce are shallow-rooted and susceptible to windthrow, especially on exposed sites, shallow soils and organic soils with water-filled hollows (Elling and Verry 1978, Fleming and Crossfield 1983, Ruel 1989).

Strip orientation is important for seed dispersal (maximum dispersion can be achieved when strips are perpendicular to predominant wind direction) and site protection. On the dry sites where the black spruce seedlings are prone to desiccation, east-west strips will provide maximum shading. Scarification may be required on both mineral and organic soils to increase the probability of natural regeneration success.

In block cutting, the removal of trees is usually in a checkerboard pattern, with blocks of uncut timber separating cut blocks. Block width is determined by site and seed dispersal characteristics, similar to those associated with strip cutting (Jeglum and Kennington 1993). Individual blocks rarely exceed 10 ha.

Strip and block cutting are not suitable regeneration options for jack pine. Although jack pine regeneration can occur along the edges of strip cuts, the seed distributed is often genetically inferior. Jack pine that can release seeds without heat have a genetic trait with negative quality associations. This trait is present at a frequency of about three percent in any jack pine population. Allowing these trees to seed and regenerate the stand will bring the frequency of this trait to about 30 percent. Negative associations of this trait are poor stem form and increased susceptibility to gall rust (Parker 1995a).

Strip and block cutting are generally not suitable regeneration options for aspen. Aspen rarely regenerates from seed - regeneration in aspen stands is primarily from coppice (suckering) (Anderson *et al.* in prep.). Apical dominance and shade from residuals inhibits suckering and reduces potential for aspen regeneration in strip and block cuts. Suckering in aspen will produce adequate regeneration in blocks of 0.4 ha or larger (Perala and Russell 1983).

**Patch** - The removal of stands in an irregularly shaped, spaced and sized cut area. Patch cuts are well-suited to harvesting in broken terrain or in stands that lack uniformity. Patch configurations are often a reflection of the mosaic in the original forest and can vary greatly in size. They are desirable because their physical dimensions can be modified to accommodate site and stand variability. In addition, patch cutting for black spruce can maximize seeding in because patch size and shape can be easily modified. Irregularly-shaped patch clearcuts provide a higher edge-to-area ratio than rectangular cuts (Chapeskie *et al*. 1989).

**Seed-tree** - The removal of all trees from an area, except for a small number of seed-bearing trees left singly or in small groups for regeneration purposes. The objective is to create an even-aged stand (OMNR 1996). Although in classical silvicultural terms, seed-tree is considered a separate silvicultural system, Ontario's Forest Management Planning (FMP) Manual (OMNR 1996) classifies it as a harvest method.

Group and single seed-tree methods require a relatively competition-free site. Logging is generally carried out using the full-tree logging method to reduce slash on site. In some cases, an inadequate seedbed can be improved with scarification.

Group seed-trees are commonly used for regenerating black spruce because susceptibility to windthrow makes it risky to use the single seed-tree method (Robinson 1970). In northwestern Ontario, experience has shown that unacceptable windthrow losses will occur if individual black spruce greater than 8 m high are left as seed trees (M. Squires 1996). Groups should be 10 to 15 m in diameter and 90 m apart. Site preparation or scarification is required except where sphagnum is abundant (Jeglum 1990).

Leaving seed trees followed by prescribed fire can successfully regenerate jack pine on fresh to moderately moist sites. Chrosciewicz (1988) found that leaving 20 healthy, well-formed and well-spaced stems per hectare on these sites, with a subsequent prescribed fire, gave a stocking of greater than 90 percent for 4 $m^2$ plots. Even though seed trees may blow down over several years, there is usually adequate seed dispersal prior to this happening.

Leaving seed trees for aspen is not recommended as a reliable regeneration option for most sites in boreal Ontario. Aspen seed has a viability period of two to three weeks and rigorous seedbed requirements (Brinkman and Roe 1975). There is limited evidence that seedling-origin aspen may dominate second-growth jack pine and upland black spruce stands in northwestern Ontario following mechanical site preparation (Marek 1983). Profuse aspen regeneration has also been reported in narrow strip cuts (Groot *et al.* 1997).

NOTE: One advantage in using seed trees to regenerate a stand is that the local gene pool is maintained.

**Harvesting with Regeneration Protection (HARP)** - The removal of the dominant canopy layer in uneven-aged lowland black spruce ecosystems. HARP protects and retains stems below a set diameter limit, leaving a significant component of the overstorey. The resulting stand is uneven-aged and uneven-sized.

HARP attempts to emulate and take advantage of a natural process in older lowland black spruce stands. These are stands that have shifted from even-aged to uneven-aged through the repetitive establishment and release of advance growth in small canopy openings created by windthrow. In these stands, black spruce can become established and persist in the understorey as “stored advance growth” at low light intensity. This advance growth has the ability to respond to increased light even after long periods of suppression (Johnstone 1978, Doucet and Boily 1986). Stand replacing disturbances, such as fire, eventually interrupt this process, recreating even-aged stands.

Although HARP is included in this guide as a harvest method under the clearcut silvicultural system, there are elements of this method that clearly do not fit the classic definition of clearcut (e.g. the resulting stand retains an overstorey and is uneven-aged).

HARP is most often confused with CLAAG (careful logging around advance growth). HARP is a harvest method applicable only in uneven-aged lowland black spruce. CLAAG is an operational practice that can be applied with any harvest method under the clearcut silvicultural system, where the objective is to remove the overstorey, protect advance growth, and regenerate an even-aged stand.

HARP has also been called thinning from above, one-cut shelterwood, heavy selection thinning, diameter limit cutting, and continuous cropping.

HARP may reduce the rotation age of some lowland black spruce stands, compared to the conventional clearcut method. HARP is now being used in northeastern Ontario, in uneven-aged, second growth stands that were horse logged up to 70 years ago. These stands are of similar quality and productivity (Groot and Mattice 1995) to mature natural stands. By applying HARP, the uneven-aged nature of these stands may be maintained through one (Groot and Mattice 1995) or more additional rotations.

**Commercial Thinning** - partial harvest of the trees in older, immature stands where some portion of the trees removed have reached a merchantable size and where the sale of the timber harvested will potentially earn a positive financial return or will be greater than the cost of logging. Commercial thinning is differentiated from a two-stage removal harvest in that the primary purpose is to enhance the growth response of the remaining residual stems. Although in classical silvicultural terms, commercial thinning is often considered a tending treatment, Ontario’s Forest Management Planning Manual (OMNR 1996) classifies it as a harvesting method because merchantable volume is being removed from the stand.

Experience and proper study of commercial thinning in Ontario’s boreal jack pine, black spruce, or aspen-dominated forests is extremely limited. In addition, the range of specific soil/site and stand conditions upon which commercial thinning has been studied is minimal. Commercial thinning is currently considered as ‘not recommended’ within the context of this document. It is subject to on-site monitoring of operational and trial-related activities when included in an approved forest management plan and associated silvicultural ground rules.

## Shelterwood Silvicultural System

The shelterwood system is an even-aged silvicultural system where mature trees are harvested in a series of two or more cuts (preparatory, seed, removal, final) for the purpose of obtaining natural regeneration under shelter of the residual trees, either by cutting uniformly over the entire stand area or in narrow strips. Regeneration is natural or artificial. Regeneration interval determines the degree of even-aged uniformity (OMNR 1996).

The advantages of the shelterwood system are that aesthetics, seed source and the local gene pool are maintained (Walstad and Kuch 1987).

The shelterwood system is generally not suitable for the regeneration of black spruce. Black spruce seedlings grow more slowly in a shelterwood stand than in open conditions. In addition, residual stems are highly susceptible to windthrow (Heinselman 1959, Groot 1994, Johnston and Smith 1983). Losee (1961, 1966) reported success using group and strip shelterwood methods in black spruce. However re-measurement of these trials forty years after establishment documented minimal regeneration within the group shelterwood and a major loss in merchantable stand volume from blowdown of the residual stems (Prairie 1994). Managers could consider using shelterwood in small, fairly windfirm black spruce where aesthetics is a major factor.

The shelterwood system is not recommended for jack pine or aspen. These species are shade-intolerant and will only regenerate adequately under full light conditions (Fowells 1965). Mixed species stands are likely to convert to other, more shade-tolerant species (Caveny and Rudolph 1970).

Modifications of the shelterwood system include harvest methods such as strip, group, uniform, and irregular shelterwood. For more information on shelterwood systems see the tolerant hardwood (OMNR 1997a) and the Great Lakes-St. Lawrence conifer (OMNR 1997b) silvicultural guides.

## Selection Silvicultural System

This is an uneven-aged silvicultural system where mature and/or undesirable trees are removed individually or in small groups over the whole area, usually in the course of one cutting cycle (OMNR 1996). The size class distribution in the residuals is similar to the original stand.

Selection is more than a reproduction system. The objective is to produce high quality products through a representation of all diameter classes (ultimately all age classes), distributed throughout the stand (OMNR 1997a).

The selection silvicultural system is not suited to the management of intolerant species such as jack pine or aspen. It is also not applicable in even-aged black spruce stands (Groot 1994). Applying the selection system on black spruce upland sites can lead to a species shift towards balsam fir and white cedar (Johnston and Smith 1983). The selection system may be biologically appropriate for the management of uneven-aged and/or uneven-sized lowland black spruce ecosystems (Groot 1994). Although research trials exist, this technique has not been applied operationally in Ontario.

# Logging Method

Logging method refers to the form of a tree when it is moved from stump to roadside, which indicates the extent and location of initial processing. Examples of logging methods include full-tree, tree-length and shortwood.

## Full-tree Logging

Full-tree logging is the removal of the whole tree to the roadside where limbing and topping occurs.

The potential for nutrient loss on sites that have been full-tree logged (Kershaw *et al*. 1997) has prompted investigations by MNR's Centre for Northern Forest Ecosystem Research and by CFS's Great Lakes Forestry Centre.

Full-tree logging will influence the number and distribution of cones left on site and the amount of slash accumulation (Bowling and Goble 1994). While this may reduce the potential for natural regeneration success, reduction of slash on the site can make it easier to plant trees.

## Tree-length Logging

Tree-length logging is the removal of only the merchantable length of the tree to the roadside. Limbing and topping occurs at the stump.

## Shortwood Logging (cut-to-length)

Shortwood logging is the limbing, topping and cutting to length of trees at the stump, followed by removal of the logs to roadside (Richardson and Makkonen 1994).

NOTE: The forest management planning manual for Ontario (OMNR 1996) uses logging method as a reference point for documenting special restrictions (e.g. type of logging equipment, season of harvest) to ensure site compatibility.

# Renewal Treatments

Forest renewal treatments are silvicultural operations undertaken to stimulate and promote the establishment of desired future forest stands. Forest renewal normally includes the activities of site preparation and regeneration (OMNR 1996).

The factors that influence the selection of a renewal treatment on a specific site are the same as those influencing the selection of a silvicultural system because in both cases, the objective is regeneration of a forest stand. These factors include:

- reproduction habits of the desired and competitor tree species
- wildlife requirements
- hazards created by insects and disease

- natural disturbance regime
- options for applying fire to reach management objectives
- climate hazards, such as frost
- size, age and vigor of the trees in the existing stand
- genetics
- management objectives/constraints

# Site Preparation

Site preparation is the disturbance of the forest floor and upper soil horizons (and/or vegetation) to create suitable conditions for artificial regeneration by mechanical or chemical means, or by prescribed burning (adapted OMNR 1996).

Scarification, a term often confused with site preparation, refers specifically to the mechanical preparation of a site for natural regeneration (see page 37).

Site preparation can involve mechanical activities, chemical applications, prescribed burning, or a combination of these techniques (Sutton 1985, OMNR 1996). Manual methods (e.g. boot screefing and hand scalping) may also be used (Jacobs and Hollstedt 1994).

## Objectives of Site Preparation

The objective of site preparation is to (Kennedy 1988, Orlander *et al*. 1990):

- create enough suitable, well-spaced sites for seedlings established from artificial planting or seeding
- provide easier access for artificial regeneration
- control competition and insect pests
- reduce fire hazard
- reduce, redistribute or align slash on the site
- manipulate wildlife habitat
- increase soil temperature and soil oxygen
- decrease frost risk
- increase availability of soil nutrients
- establish seedlings quickly
- maximize seedling survival rates

## Soil Characteristics and Site Preparation

The inherent productivity potential of a site is tied to soil conditions. Soil characteristics must be considered when developing a site preparation prescription (Spittlehouse and Stathers 1990).

Soil organic matter:

- holds nutrients
- is essential to biological activity from soil mycorrhizae and microbial activity
- helps to retain soil moisture and porosity
- in the duff layer protects soil from structural damage and erosion

Optimal soil porosity:

- promotes root growth
- permits air and water movement in soil
- is necessary for good drainage and biological activity

## Considerations Around Site Preparation

Site preparation can be a very effective silvicultural tool, but it also presents significant potential for excessive disturbance and damage to sites (Walstad and Kuch 1987, Von der Gonna 1992). To be optimally effective in achieving management objectives, and to mitigate the potential for site damage, site preparation treatments must be matched to the site, employed at the appropriate intensity and applied at the right time. There is considerable concern about the level of intensity of site preparation. Excessive soil disturbance can lead to nutrient deficiencies, compaction, erosion and other forms of site degradation. Insufficient levels of disturbance, however, may result in a failure to meet management objectives (Von der Gonna 1992).

Site preparation:

- should, where possible, mimic a natural disturbance that gives the desired species an advantage - or a competitor a disadvantage (Oliver and Larson 1990)
- should, where possible, mix organic material with mineral soil on shallow, low fertility sites, and not remove slash and humus (Foster and Morrison 1987, Kershaw *et al.* 1997)
- should be done as soon as possible after harvest on the more competitive sites, to avoid development of competition and to take advantage of seed dispersal opportunities from standing trees and logging slash (Jeglum 1984, Walker and Sims 1984, Fleming and Mossa 1996)
- may not be necessary on organic soils with adequate advance growth or suitable sphagnum seedbeds
- should consider that site degradation may occur through nutrient loss, soil compaction and erosion, especially on steep slopes (Walstad and Kuch 1987), which can reduce conifer growth even though competition is minimal (Sutton 1985, Wood and Dominy 1988, Groot and Carlson 1996)
- should consider the silvics of the desired species (e.g. damage and mortality may occur from late spring or early fall frosts through excessive seedling exposure)

NOTE: A light vegetative cover may provide frost protection while interfering little with growth (Sutton 1984, Lundmark and Hallgren 1987).

- should retain soil mycorrhizae, which promote seedling growth (Maser *et al*. 1978)
- can promote the growth of grasses, sedges and cattails in wet areas
- can promote growth of competitors from the seedbank, such as raspberry and pin cherry (Sutton 1985, Weetman and Vyse 1990)
- can cause soil compaction in wet soils and soils with a high clay content

NOTE: Soils can recover from compaction, but it can take decades. Coarse soils can recover within two years, while clay loam tills can take up to 21 years (Corns 1988).

- may create a drier and more nutrient-poor microsite, if organic material is displaced beyond the rooting zone (Weetman and Vyse 1990)
- may lead to drying out and frost heaving on fine textured soils when the organic layer is removed
- may result in short-term reduction in vegetative cover, while promoting later resprouting (MacKinnon and McMinn 1988)
- can promote decay in some species, such as aspen, through root and stem damage (Basham 1982)
- may lead to the loss of advance growth
- can provide seedbeds for the germination of windblown seeds

## Considering Competitors in Site Preparation

Non-crop or competitive vegetation on a site can have a positive or negative affect on crop-tree performance (Newton and Comeau 1990). Competitors can:

- capture and store nutrients and recycle what might otherwise be lost from the ecosystem through leaching, erosion, etc.
- improve soil physical and chemical properties by adding organic matter and, with some species, by fixing nitrogen (e.g. alders)
- interfere with insect movements (e.g. leader weevils and some sawflies)
- be alternate hosts for mycorrhizal fungi, and thus can maintain their populations
- protect seedlings from browse damage, and provide a browse species and food source for wildlife
- reduce air and soil temperatures
- compete with tree seedlings for light, water and nutrients
- contribute to physical damage from snow loading, vegetation falling on seedlings, and wind whip of conifer leaders

- inhibit seedling growth
- provide habitat for small mammals that may damage seedlings
- provide an alternate host for insects and diseases
- increase seedling mortality
- inhibit access to the site for subsequent treatment

## Mechanical site preparation

Mechanical site preparation involves the direct use of machinery to modify a site to provide favorable conditions for artificial regeneration and/or to improve access (Smith 1986, Sutherland and Foreman 1995). A primary objective of mechanical site preparation is to strike a balance between enhancing short-term nutrient availability for seedlings and preserving the longer-term nutrient capital of the site (Sutherland and Ryans in prep.).

Mixtures of well decomposed organic matter with mineral soil provide the best seedbeds and planting sites on sandy or loamy soils. On fine-textured soils, minimal mineral soil exposure is desirable due to the risk of seedling mortality from frost heaving (Walstad and Kuch 1987, Sutherland and Foreman 1995). For further information see Sutherland and Ryans in *Regenerating Ontario's Forests* (Colombo and Wagner in prep).

Consider the following when developing a prescription that includes a mechanical site preparation treatment:

- topography
- soil type, texture and moisture regime
- microsite conditions required to promote regeneration of the desired species (Sutherland and Foreman 1995)
- amount of ground overburden, including humus layer, vegetation, residuals, slash loading and surface stoniness
- follow-up treatments (e.g. tending)
- available equipment

Mechanical site preparation is not suitable for application under some conditions (Walstad and Kuch 1987, Von der Gonna 1992), including:

- sites with adequate natural seedbeds
- sites with adequate amounts of advance regeneration
- wet pockets within otherwise suitable areas
- sites with high amounts of surface stones and boulders
- steep slopes
- shallow sites or sites with thin organic layers

There are five broad categories of mechanical site preparation, and they vary in the amount of disturbance of the forest floor, and in the degree of mixing of the organic layers with the underlying mineral soil. The five categories are screefing, mounding, inverting, trenching, and mixing.

**Screefing** (including scalping and shearblading) is the paring off of low and surface vegetation with most of its roots prior to seeding or planting, resulting in an exposed soil surface (NRC 1995).

Screefing differs between upland and lowland sites. In upland screefing, the objective is to remove or displace the organic layer in order to expose and/or lightly disturb the underlying mineral soil. In contrast, lowland screefing exposes and/or removes only the top layers of sphagnum moss on organic soils and partly compacts the lower layer. The mineral soil is not disturbed in lowland screefing (Sutherland and Foreman 1995). Lowland screefing is effective for the establishment and growth of black spruce seedlings.

Shearblading is restricted to stone-free soils. Winter shearblading cuts off competing woody vegetation and is the preferred mechanical site preparation method for peatland black spruce sites where there is minimal advance regeneration. On these sites, 25 percent seedbed exposure is recommended, but acceptable results have been obtained with only 14 percent exposure (Jeglum 1984).

Scalping (patch site preparation) on shallow sites is adequate to regenerate black spruce by planting, with minimal site disturbance. Consult the *Forest Management Guidelines for the Protection of the Physical Environment* (Archibald *et al.* 1997) whenever considering site preparation treatments on shallow sites. Patch site preparation is generally not suitable for aerial seeding areas due to low mineral soil exposure (Bell *et al*. 1992).

**Mounding** is a form of spot site preparation where raised planting spots are created. The soil warms quickly, seedling growth starts earlier and competition may be held back. Seedlings should be deep planted for optimal survival with the root collar at least 5 cm below surface (Von der Gonna 1992). Mounds should be 10 to 30 cm in height after settling (actual dimensions will vary based on site-specific environmental concerns), and should be wide enough to control competition. They should have flat to concave tops (for collecting rainwater), gently sloping sides, and have good contact with the humus or soil layers below. Mounding is not suitable for peat soils (Brown 1983a), or in areas with heavy competition (Bell *et al*. 1992).

**Inverting** involves “flipping over” parts of the forest floor organic layer, with or without the underlying mineral soil, onto the adjacent undisturbed forest floor. The desirable seedbed or microsite is on top of the inverted layer. The inverted layer may be broken, but no mixing takes place between the inverted mineral soil layer and the undisturbed duff. Inverting can be done either as regularly spaced spots, or as continuous strips (Sutherland and Foreman 1995).

The limitations of inverting include:

- drying out of mineral soil layer if it is inverted
- ineffectiveness on sites with abundant competition
- drying out and frost heaving on fine mineral soils such as clays (McMinn and Hedin 1990)

**Trenching** involves removing and mixing of both the mineral soil and organic layers into berms on top of the adjacent, undisturbed forest floor (Sutherland and Foreman 1995). The desirable seedbed or microsite lies within the trench, not on the berm. On dry sites, trenching allows the accumulation of water after rainfall for seedling use (Bell *et al*. 1992). Trenching is generally done using disc trenchers, cone trenchers or heavy barrel drags.

Trenching is not suitable on clays or other fine soils, due to frost heaving or drying out (McMinn and Hedin 1990). On productive sites, vegetation competition may be high on the raised berms (Bell *et al*. 1992). Sides of berms are also prone to drying out.

**Mixing** is the incorporation of the organic layer into the underlying mineral soil, along with fine debris, using rotating tillers or other devices (NRC 1995, Sutherland and Foreman 1995). This technique is suitable for coarse and medium textured soils. Mixing avoids the problems of waterlogging or restricted root growth from compaction. Mixing may be better than scalping for fine-textured soils (McMinn and Hedin 1990). Equipment used for mixing includes agricultural-type discs, bedding plows and rotary mixers.

Mixing may encourage resprouting of competing vegetation (Sutherland and Foreman 1995). Mixing is not suitable for stony or rough ground. It may cause long-term nutrient depletion from leaching. Too many nutrients are available after disturbance, and plants cannot take them up fast enough. This can be avoided by only mixing the planting spots (McMinn and Hedin 1990).

## Chemical Site Preparation

Chemical site preparation involves applying herbicide to a site prior to regeneration. This treatment can be used alone or in combination with other types of site preparation. For example, chemical site preparation can be used before a prescribed burn (brown and burn) to enhance the effectiveness of the burn (Buse and Bell 1992). It can also be used before, during or after mechanical site preparation to reduce competing vegetation. The purpose of chemical site preparation is to control competing vegetation and their effects on crop trees that will be seeded, planted or naturally regenerated. This is accomplished by killing the existing vegetation and/or preventing new vegetation regenerating from seed (Campbell *et al*. in prep.).

Commonly used chemicals in the Boreal Forest of Ontario include 2,4-D (controls alder on organic soils and susceptible woody shrubs on upland areas) (Buse and Bell 1992), hexazinone (a pre-emergent treatment for use on grasses, sedges, raspberries and other species), and triclopyr and glyphosate (broad spectrum control of woody species) (Arnup *et al.* 1995).

Before undertaking a spraying program, a wide range of technical, social, political and legal issues must be addressed (Boyd 1982, Walstad and Kuch 1987, OMNR 1991a, Brand 1992).

Chemical site preparation:

- is more effective in reducing competition than other site preparation methods (Bell *et al*. 1992)
- can be used on almost any type of terrain, any size of area, using a variety of techniques and at different times of the year
- does not disturb the surface soil, therefore wind-borne seeds are not given the opportunity to germinate
- can be used as a stand-alone treatment on shallow, very shallow or rocky sites and steep slopes, where mechanical site preparation is not practical
- allows for minimal soil disturbance (and consequent nutrient loss) with no losses in inherent site productivity (Walstad and Kuch 1987)
- may be more effective before planting spruce rather than chemical cleaning one year after planting (Wood and von Althen 1993)
- can be used in areas with advance regeneration (after hardening off)
- indirectly controls tree-damaging rodents (Boyd 1982)
- does not usually stimulate the soil seedbank (Boyd 1982)

The following are other considerations around the use of this site preparation treatment:

- chemical site preparation can be limited in effectiveness if the target species is not susceptible to the chemical (McMinn and Hedin 1990)
- seasonal restrictions relate to susceptibility of competitors and conifers, as they must be applied when the competitors are in leaf (Walstad and Kuch 1987) and conifers are hardened off
- chemical site preparation is usually limited to vegetation less than 2 m tall, with ground application (Bell *et al*. 1992)
- some seedbank species (e.g. pin cherry) can be stimulated by herbicide application (Mallik *et al*. 1996)
- vegetation can resprout if the chemical is not translocated to the rootstock/ rhizome (Bell *et al.* 1992)

Certain sites are more suitable for chemical site preparation than others. It is most effective on sites with high competition or where soil compaction may be a hazard, especially on wet or clay soils.

Although not widely used in Ontario, chemical site preparation can be used to regenerate aspen stands. Herbicides would remove unwanted residuals, either through a cut surface application or aerial spraying (Perala 1977). Spraying has to be done before new suckers are initiated.

**Broadcast spraying** is the most frequently used method of chemical site preparation. It treats an entire area using aerial or ground-based equipment.

**Band spraying** applies herbicide downward in a band of selected width with ground-based equipment. This method can be tailored to small areas, boundaries or buffer strips, and has less restrictive environmental conditions for application than broadcast spraying.

**Spot spraying** involves the treatment of a small specific area using ground-based equipment, directly targeting the seedling microsite or specific competitors. This allows much greater control on spray area and target species.

## Prescribed Burning

Prescribed burning is the knowledgeable application of fire to a specific land area to accomplish predetermined forest management or other land management objectives (Merrill and Alexander 1987). It most closely emulates natural processes, especially in fire-evolved ecosystems such as jack pine and black spruce forests. Forest ecosystem classifications are useful in determining suitability of sites for prescribed burning. For example, sites dominated by lichens or feathermosses can dry more quickly and have a faster rate of spread than sites with sphagnum substrates (McRae and Blake 1995). Rough and bouldery sites where mechanical site preparation would be difficult may be especially suited to prescribed burning (Walstad and Kuch 1987).

Prescribed burning is not currently used in Ontario to site prepare aspen stands although it is suitable for regenerating aspen when carried out immediately following harvest and prior to initial root suckering. In other provinces, medium severity burns are considered optimal for the removal of slash, humus, brush, residuals, and for the promotion of adequate suckering (Horton and Hopkins 1965). Light severity burns do not remove enough litter and organic material for sufficient suckering. High severity burns may damage root systems (Perala 1974), and can be used to reduce aspen suckering.

The Prescribed Burn Planning Manual (OMNR 1995d) presents the procedures for prescribed burning in Ontario. Predictive models have been developed to show the relationship between fuel consumption and the buildup index (BUI) for jack pine logging slash (Stocks and Walker 1972, McRae 1979). Tools such as these allow forest and fire managers to predict the degree of success of prescribed burns.

Objectives of prescribed burning include (McRae 1979):

- preparing the site for regeneration
- removing or controlling undesirable species, promoting the growth of desirable species
- reducing the fire hazard from logging slash

Some of the benefits of prescribed burning include (Chrosciewicz 1976, McRae 1979, 1995, Aksamit and Irving 1984, Archibald and Baker 1989, Bell *et al*. 1992, Luke *et al*. 1993, Archibald *et al*. 1994):

- production of a suitable seedbed for natural or artificial seeding

- removal of slash to provide planter access and more planting spots (McRae *et al.* in prep.)
- improvement of the soil nutrient regime with increased levels of nutrient cations and faster mineralization rates (McRae 1986)
- creation of higher soil temperatures and longer growing season with removal of insulating organic layer
- avoidance of soil compaction and rutting, especially where mechanical site preparation is not advisable (Sutton 1985)
- control of some pests (Johnston 1971)

To increase success of a prescribed burn (McRae 1995):

- co-ordinate with fire personnel during the planning stages of the cut
- ensure the perimeter of the burn is as small as possible
- take advantage of natural firebreaks such as wetlands and hardwood stands
- burn the first season after logging
- assess slash conditions after harvest to determine the burn potential
- remove all unmerchantable stems near the cutblock edge to prevent firebrands being sent over firebreaks by wind or convection columns
- ensure that no slash is present around the perimeter

Prescribed burning is not without some hazards or disadvantages. Burning is not recommended during high fire indices. Severe burns can result in removal of most or all of the organic layer. This increases the risk of erosion, especially on steep slopes, and nutrient loss. On very shallow sites where it is important to conserve slash and organic material for site protection, only low-severity burns should be used (Bell *et al*. 1992). Severe burns may be required to produce adequate seedbeds for direct seeding on some upland black spruce and jack pine sites (Chrosciewicz 1970). Complete mineral soil exposure may be harmful if the soil is nutritionally poor, drains very rapidly, has a low water retention capacity, or frost heaves when exposed. The objective of most silvicultural uses of fire is not the total destruction of mor or peat materials present, but rather their reduction to a degree sufficient for prompt re-establishment of favorably stocked stands either by planting or by seeding (Chrosciewicz 1978a,b).

Prescribed fire is not a suitable method for releasing seed from cones found in slash because the seed will either be consumed or lose its viability because of high temperatures (Chrosciewicz 1978a,b).

The effect of prescribed fire on competing vegetation is mostly of a temporary nature, but stand dynamics can be affected over the long term (Methven and Murray 1974, Jeglum and Kennington 1993).

Other considerations include (Bell *et al*. 1992, McRae 1995):

- risks associated with the escape of fires
- effects of weather on burn success

- incompatibility of burning with advance regeneration
- effects of site moisture conditions and fuel distribution on burn success
- potential for increased competition on highly competitive sites (Johnston 1971)
- potential for insect problems (e.g. black army cutworm) following the burn

# Regeneration

Regeneration is the establishment of a tree crop by natural (self-sown seed or by vegetative means) or artificial means (seeding and planting). Regeneration may also be used to describe the young crop itself (OMNR 1996).

Taking active steps to regenerate a site is often necessary to achieve management objectives and reach a desired future forest condition. Disturbed stands will regenerate on their own, as they have done for thousands of years. The problem is that the naturally regenerated stand may not meet management objectives. Taking steps to influence regeneration will help meet these objectives through the control of stand composition and structure.

## Selecting a Regeneration Method

There are many factors that influence the selection of a regeneration method, including:

- reproduction habits of the desired and competitive species
- access to site
- availability of nursery stock and/or seed
- availability of seed on-site
- slash volume and distribution
- availability of microsites
- management objectives
- management constraints
- pre-harvest stand characteristics
- quantity and distribution of advance growth
- site type or ecosite
- site characteristics, limitations and hazard potential

Regeneration treatments fall into two broad categories, natural and artificial. Combinations of natural and artificial regeneration (assisted natural or blended) can be effective under some conditions.

## Natural Regeneration

Natural regeneration is the establishment of a tree crop by natural seeding, sprouting, suckering, or layering (NRC 1995, OMNR 1996).

Natural regeneration requires the successful completion of a chain of events involving flowering, cone development, seed dispersal, germination, establishment and early seedling growth. If this chain is broken, (e.g. drought limiting seedling establishment), it can result in regeneration failure and a delay in renewing the site. It also requires a lengthy regeneration period, increasing the rotation age. For example, five-year-old black spruce from seed were only 20 cm, while black spruce planted at the same time were 68 cm tall (Wood and Jeglum 1984).

Natural regeneration presents opportunities to maintain local gene pools. Higher initial stem densities can be achieved compared to planted stands, resulting in better stem quality compared to planted stands (Janas and Brand 1988). However, it provides less control over spacing, density and species composition compared to artificial regeneration. The next stand will have more variable stocking, clumping and species composition compared to planted stands.

**Advance growth** is composed of trees younger than the canopy by at least several decades, which established naturally from seed or layering in the shade of the current overstorey (Oliver and Larson 1990, Walsh and Wickware 1991, Buse and Farnsworth 1995). Advance growth is usually composed of species that are mid-tolerant to tolerant of shade which can be of a different species than the overstorey (Weetman and Vyse 1990).

In the Boreal Forest, balsam fir, black spruce, white spruce and white cedar may occur as advance growth. Depending on the development stage of the advance growth, rotations can be reduced by 20 to 30 years (Archibald and Arnup 1993) compared to stands established after logging. The use of advance growth as the primary method for regenerating a stand is most often used in lowland black spruce. On upland sites, advance growth may be used to enhance other regeneration treatments (planting or seeding).

**Natural seeding** is the dispersal, by natural agents, of seeds from standing trees in proximity to a regenerating area, or from slash scattered over that area. Seeds may be dispersed by wind, birds, mammals, gravity or flowing water, or be released by fire from serotinous cones (NRC 1995). Seed release patterns depend on cone location and substrate (Cayford *et al.* 1967, Bowling and Niznowski 1991, Boisvenue *et al.* 1994, Fleming and Mossa 1996).

Advantages of natural seeding include local gene pool maintenance, improved seedling root form and a more diverse future stand (Weetman and Vyse 1990). Disadvantages may include less control over stand composition and structure, and increased risk of germination failure of new seedlings due to adverse climatic conditions.

To achieve natural seeding from standing trees in or adjacent to a cut area, the source trees need to be healthy and wind-firm long enough for them to drop seed.

In black spruce, natural seeding is generally achieved from standing trees adjacent to or remaining in a cut area. Maximum success can be achieved when a good seed year is combined with a suitable seedbed and adequate moisture during the growing season. On lowland organic sites, sphagnum mosses are good seedbeds (Groot 1988), while on uplands, establishment is best on seedbeds close to the interface of the mineral soil and humus layers (Fleming and Mossa 1994).

In jack pine, natural seeding can be achieved through the seed-tree method with prescribed burning (Chrosciewicz 1988), or through cone scattering without prescribed burning (Boisvenue *et al.* 1994). Scarification is often used to redistribute slash and create suitable microsites for natural seeding.

NOTE: Scarification (includes cone scattering), for the purposes of forest management planning in Ontario (OMNR 1996), is considered an assisted-natural regeneration method and is addressed in the artificial regeneration section of this guide (see page 37).

Groot *et al.* (1997) provide an excellent overview on the use of planned natural regeneration in Ontario.

In aspen, natural seeding is not a recommended technique for regenerating stands. At most, aspen seed is viable for two to three weeks after dispersal (Navratil 1991) and seedbed conditions are critical. The seedbed must be moist, have moderate temperatures, good drainage and be free of competition during germination and establishment (Steneker 1976).

**Vegetative Regeneration** (coppice) refers to natural regeneration originating from stump sprouts, stool shoots or root suckers (NRC 1995). A coppice shoot is any shoot arising from an adventitious or dormant bud near the base of a woody plant that has been cut back. Sprouts are any shoots that arise from a plant, particularly from the base of a plant, either from the stool or the root. Suckers are shoots that originate from adventitious buds on roots.

Vegetative regeneration, mainly root suckering, is the primary method of renewing aspen stands. Most suckers originate from roots 0.8 to 1.8 cm in diameter and within 8 cm of the surface. Soil temperature is the most important environmental factor controlling sucker formation. Optimal formation is at 23 C (Maini and Horton 1966). The majority of suckers are produced in the first growing season after disturbance (Sandberg 1951).

Vegetative regeneration can provide for rapid stand establishment, often at a comparatively low cost (usually just the cost of logging). Maintenance of the local gene pool can be an advantage or a disadvantage, depending on the genetic composition of the stand.

To maximize sucker production, completely remove the overstorey to remove apical dominance. This can result in over 20,000 shoots/ha (Jones 1975). Single tree removal in aspen stands does not promote suckering (Stoeckler and Macon 1956). In addition, competing woody shrubs tend to occupy these selectively cut sites and limit aspen sucker survival (Doucet 1989).

Harvesting aspen in the dormant season generally results in maximum aspen suckering during the next growing season, but after two or three years, stem density is just as high on summer-logged as on winter-logged areas (Peterson and Peterson 1992). Winter harvesting also reduces soil compaction and mechanical damage to the root systems.

Sufficient stocking can be attained with summer logging on drier sites, especially in late summer (Bella and DeFranceschi 1972, Perala 1981, Bates *et al*. 1993). Clearcutting aspen in the spring may provide substantial suckering in the same growing season (Schier *et al*. 1985).

Aspen is sensitive to disturbance on poorly drained, fine-textured soils. With excessive disturbance from rutting and soil scarification, regeneration failure can occur, especially with early summer logging (Bates *et al*. 1993).

Perala (1981) indicated that only 120 parent stems/ha are needed to achieve full stocking to aspen, provided that the stems were not more than 8 to 10 m apart. Doucet (1989) found that only 5 $m^2$ basal area/ha in the original stand is needed for full stocking to aspen.

Stand age does not generally affect suckering ability, provided the stand is not breaking up because of decay (Steneker 1976). Overmature stands may have inadequate suckering ability because of shrinking root systems. Sometimes pathogens or defoliating insects can cause premature break-up (Perala 1991).

## Blended Regeneration

Blended regeneration involves a combination of natural and artificial regeneration for establishing black spruce and jack pine stands. Usually this involves seeding or planting to compliment advanced growth and ingress densities.

## Artificial Regeneration

Artificial regeneration is the establishment of a tree crop by either direct seeding or planting seedlings or cuttings (NRC 1995, OMNR 1996).

### Seeding

**Direct seeding** involves artificially applying seeds by manual or mechanical means to an area for forest regeneration (Daniel *et al*. 1979).

Seeding is generally successful on areas with little competition. The advantages of seeding over planting include

- elimination of storage and transportation requirements associated with nursery stock
- wider time window for seeding over planting
- administratively simpler system
- promotion of a naturally developed root system (Cayford 1974)
- seed losses to mice and voles are not usually a problem with black spruce or jack pine (Martell *et al*. 1995).

Direct seeding includes broadcast seeding and precision seeding.

**Broadcast seeding** is the sowing of seeds more or less evenly over a whole area on which a forest stand is to be established (Haddon 1988). Seeding is usually done in late winter to early spring. Broadcast seeding can be applied with aerial or ground-based equipment.

Some limitations of broadcast seeding include:

- difficulty in achieving uniform seed distribution (Bell *et al.* 1992). Limitations of some equipment can result in an uneven distribution of seed across the site at certain application rates (Foreman and Riley 1979). This problem is more pronounced with black spruce than with jack pine (Fleming *et al.* 1985)
- high dependence on site conditions, leading to inconsistent results, especially with black spruce on upland sites (Richardson 1974).
- potential inefficient use of improved seed (i.e. many seeds fall on poor microsites).
- predisposition of small size germinants to competition or drought (Bell *et al.* 1992).

Stocking levels are more directly related to the amount of receptive seedbed available than to the amount of seed applied (Riley 1980, Fleming and Mossa 1995). To achieve adequate stocking in black spruce with either natural or artificial seeding, sites require at least 10 to 15 percent coverage by a receptive seedbed such as sphagnum. With artificial seeding, a rate of 100,000 seeds/ha is recommended (Groot 1994).

Forest managers should consider the delayed germination effect, especially with jack pine, before declaring any seeding project a failure. There is a very real danger that an assessment made too early (i.e. after one season) will indicate inadequate stocking (Riley 1973). Two or three seasons may be required to allow for delayed germination and to get an accurate assessment of treatment success (Nelson 1977, Boisvenue *et al.* 1994). Seeding rates should also be adjusted to take into consideration expected levels of ingress.

Broadcast seeding is currently used in the northern Clay Belt on organic sites (Ecological Services for Planning 1988) and is used extensively and quite successfully for jack pine regeneration across the Boreal Forest in Ontario (Brown 1983b). Seeding rates should be adjusted to account for expected levels of ingress. Experience with upland jack pine sites indicates that over-dense stands often result when standard seeding rates are used (Riley 1980, Van Damme and McKee 1990, Whaley and Buse 1996, Bulley and Bowling 1997).

**Precision seeding** is the artificial systematic sowing of seeds by manual or mechanical means in an area on which a forest stand is to be grown (adapted NRC 1995). Precision seeding can be done either as spot seeding (sowing of seed within small, prepared patches) with or without shelters, or as drill (row) seeding (sowing of seed in shallow furrows across an area) (Haddon 1988, Davidson 1992, Sidders 1993).

Advantages of precision seeding include making the best use of the available seed resource (Dominy and Wood 1986, Adams 1995) and controlling spacing and density (Corbett 1992). Future stocking and density is dependent on amount and distribution of receptive seedbeds and on seed application rate. For example, hand seeding of five to eight black spruce seeds per seed spot has, in combination with tending treatments, given a stocking rate of 40 percent or better on suitably prepared sites (Fraser 1981, Whaley *et al.* 1996). Soil compaction can enhance success of direct seeded jack pine (Van Damme *et al.* 1992)

In northwestern Ontario, the greatest likelihood for black spruce seeding success is on organic soils characteristic of ecosites ES34 to ES36. Jack pine seeding success will be highest on ecosites ES11 to ES15, and ES18. Greatest success with precision seeding on peatlands is on poorly decomposed undisturbed sphagnum peat, followed by sheared sphagnum, and live compact sphagnum. Height of black spruce seedlings ranged from 8 to 17 cm after five years across these seedbed types in northeastern Ontario (Groot and Adams 1994). Greatest likelihood of success for black spruce in northeastern Ontario is on FEC site types ST8, ST11, ST12, ST13 (Groot *et al*. 1995). Precision seeding is not generally a viable option on fertile sites (Dominy and Wood 1986, Whaley *et al.* 1996), although site preparation can increase seeding success on northwest vegetation type V33 for black spruce and on V31 to V33 for jack pine.

Stocking can be increased with sheltercones when precision seeding black spruce and jack pine. Sheltercones may also be beneficial on exposed or cold sites for improved germination and seedling development (Dominy and Wood 1986). For black spruce on upland sites or mineral soil seedbeds, sheltercones increase survival and growth rates, however, they have no effect on survival and growth rates on peatlands (Wood and Jeglum 1984, Campbell and Baker 1989, Adams 1995).

## Planting

Planting is establishing a forest by setting out seedlings, transplants, or cuttings in an area (NRC 1995).

Planting, compared to other regeneration methods, provides the greatest control over stand density and structure to achieve management objectives. It is also generally the most intensive and expensive option. Planting is suitable for a wide range of sites, and is often the regeneration option chosen for productive, competitive or degraded sites.

Planting may provide (Bell *et al.* 1992):

- a choice of stock types
- a faster and often more successful method of re-establishing crop trees on a site
- an opportunity to match growing stock to the site
- control over species composition, spacing and density
- an opportunity to change species composition (e.g. balsam fir to black spruce dominated stands)
- an opportunity to introduce genetically improved stock (faster growth rates, disease resistance)
- uniformly-spaced planted stands can be more productive than stands established by seeding or other natural methods (Stiell 1982). High density stands from seeding (either natural or artificial) can stagnate and grow slowly in diameter (Janas and Brand 1988).

Before selecting planting as a regeneration option, consider the following:

- Can other, less intensive, regeneration options be employed (Bryson and Van Damme 1994)?
- Is the stock from an appropriate seed source, reducing the risk of maladaptation (Joyce *et al.* 1995)?
- Is stock available and is the stock type and species well matched to site conditions?
- Is direct planting, without site preparation, an option?
- Is deep planting appropriate for the site (Schwan 1994)?
- Is area-based planting an option (Wiensczyk 1990)?
- Is spacing appropriate for management objectives (Willcocks and Bell 1995)?
- Will ingress of naturals cause overstocking (Willcocks and Bell 1995)?
- Is local seed available, making it possible to maintain the local gene pool?
- Could herbivory reduce success, as nursery seedlings can be more desirable to snowshoe hares than naturally regenerated seedlings (Rodgers *et al.* 1993)?

NOTE: Site type or ecosite, site preparation method employed, and the type of planting tool used can influence the number and distribution of planting spots (McClain and Willcocks 1988).

Two different planting stocks in common use in Ontario are bare-root and container.

**Container stock** refers to seedlings, grown in containers, that will be planted with roots still in the growing medium (NRC 1995).

**Bare-root stock** refers to seedlings that will be planted with their roots bare of soil (NRC 1995).

In selecting planting stock, a number of factors should be considered, including (Mohammed et al. in prep.):

- field survival, growth rate, wood quality, stress resistance, and capacity to withstand competition
- length of planting season
- site characteristics, such as soil depth, texture, and amount of slash
- handling and planting characteristics of the stock (Cleary *et al*. 1978, Grossnickle and Blake 1987)
- type of site preparation and subsequent tending treatments
- degree of competition on the site
- lead time required to obtain stock

## Seedling Quality

Nursery managers need to ensure that only vigorous seedling stock is shipped. Similarly, forest managers need to be assured, usually within a short time frame, that their planting stock is healthy. A small difference in initial vigor can translate into growth differences that may be maintained over the life of a tree. These differences in growth when accumulated over large areas and many years can affect forest objectives.

Seedling quality may be affected by nursery practices, storage and handling. Seedling quality may be determined by observation of physical attributes such as the presence of mould, dead needles, and other features described in literature on stock handling and storage. To reduce the likelihood of planting unhealthy seedlings, seedlings should be inspected before shipping, and monitored regularly in the field by trained individuals. Quality may be more accurately determined through standardized tests that assess the seedlings' physiological state.

Standardized tests are available to determine root growth potential, chlorophyll fluorescence, stress-induced volatile emissions, and visual signs of damage or pathogens (Colombo *et al.* in prep.).

## Scarification

Scarification is the loosening of the top soil of open areas or the breaking up of the forest floor, to assist the germination of natural seed from either standing trees or slash, or to stimulate suckering and sprouting (adapted NRC 1995). Scarification, for the purposes of forest management planning in Ontario (OMNR 1996), is considered an <u>assisted-natural</u> regeneration method and is addressed in this <u>artificial regeneration</u> section. This method applies mechanical site preparation techniques, while relying on natural seed sources or root systems.

Scarifying to assist in the germination of seed from standing trees involves manipulating the organic mat to achieve a uniform distribution of suitable seedbed (Chrosciewicz 1990).

Scarifying to assist in the germination of seed from slash involves manipulating the organic mat to achieve a uniform distribution of suitable seedbed, and/or redistributing or adjusting cone-bearing slash (cone scattering) to provide for the release of seeds (Chrosciewicz 1960, Chrosciewicz 1990). Seed can be released from serotinous cones within 30 cm of the ground (Cayford *et al.* 1967, Bowling and Niznowski 1991, Boisvenue *et al.* 1994). More cones are available in older stands (greater than 80 years) (Bowling and Niznowski 1991). Cone scattering is not compatible with full-tree logging or other methods that remove slash from the site.

Where aspen is a crop species, duff removal will stimulate suckering with earlier warming of the soil. Scarification should not be done in cut aspen stands after suckering has started, due to reduced height growth in the replacement suckers (Weingartner 1980). Winter shearblading maximizes aspen sucker production with minimal damage to the parent root systems (Perala 1977).

Consider the following in selecting scarification as a regeneration method:

- ground roughness and topography
- ecosite (site type)
- slash volume and depth
- organic mat thickness
- potential for competing vegetation
- stand age
- logging method
- season of harvest
- time since harvest

## Tending Treatments

Tending is any operation that is carried out to improve the growth or quality of a forest stand. Tending may involve cleaning (i.e. removal of undesirable or competing vegetation), thinning, stand improvement or pruning (adapted OMNR 1996).

### Selecting a Tending Treatment

Consider the following when developing a prescription for a tending treatment (Jaciw 1969):

- accessibility and topography
- management objectives
- size and extent of competition
- desired species
- environmental constraints
- value of end product
- equipment and labor availability

### Cleaning

Cleaning is an operation in a young stand to reduce, eliminate or suppress undesirable competing vegetation. Cleaning promotes growth in crop trees by removing competing vegetation of similar age that overtops them or is likely to do so. Cleaning may be accomplished by manual, mechanical or chemical means, or any combination thereof.

Cleaning allows crop trees to establish rapid dominance of the site, increasing survival and growth in the important establishment stage. Long-term benefits include an enhanced ability to meet management objectives for a future forest condition and an increase in merchantable volume.

Cleaning provides the most benefits when it is applied before competing vegetation has impeded growth in crop seedlings (Wood and Dominy 1988). In spruce stands, cleaning should be done before crop seedlings display visible signs of suppression, as the release response is slow once they have been suppressed. In a study by Whaley *et al.* (in prep.), three years after cleaning, five-year-old black spruce had 2.5 times the volume of corresponding trees which had not been cleaned.

Cleaning is not always necessary. Competing vegetation does not always have a level of impact on crop tree survival or growth that warrants an investment in cleaning (Oliver and Larson 1990). It may be beneficial to retain competition on some sites. For example, competition can protect white spruce seedlings from late frosts (Wood and Dominy 1988).

**Manual cleaning** involves the use of hand pulling or hand tools (e.g. motorized brush saws, chain saws, axes) to reduce, eliminate or suppress competing vegetation around crop trees. It is highly selective and the most socially acceptable method of vegetation management (Bell *et al.* 1992). However, it is costly and labor intensive compared to other methods. It is most practicable on small sites such as research plots, seed orchards or elite plantations, public areas and small tracts (Walstad and Kuch 1987, Bulley and Bowling 1997).

**Mechanical cleaning** involves the use of wheeled or tracked machines to reduce, eliminate or suppress competition. This method is less effective with species that sucker readily, as mechanical cleaning may promote sucker growth (Arnup *et al*. 1995). It does not remove root competition.

**Chemical cleaning** involves the use of herbicides to reduce, eliminate or suppress competition. Chemicals can be applied through aerial spraying, or through on-ground treatments involving vehicle-mounted equipment, backpack sprayers, or other hand applications tools.

Consider the following in developing a chemical cleaning treatment prescription:

- Conifer seedlings can be damaged if sprayed before buds have set and the leaders have hardened off (for spruce and jack pine it is usually safe to spray after mid-July) (Walstad and Kuch 1987, Carruthers and Towill 1988).
- The height and distribution of crop trees may limit use of some mechanical or vehicle-mounted equipment, because of potential physical damage to the seedlings.
- Combining chemical and manual treatments can be effective in cleaning operations to control coppice growth. For example, brush saws with an attached herbicide applicator can be used to apply a systemic herbicide while cutting stems (McLaughlan 1993).

In Ontario, the majority of cleaning is accomplished by aerial herbicide spraying (Towill *et al.* 1988, Krishka and Towill 1989a,b).

When using herbicides, managers and operators should refer to the autecology section and product labels for information on product registration and efficacy, species sensitivity and recommended timing of application.

# Spacing

Spacing refers to thinning operations that reduce the number of stems in a stand to accelerate diameter growth or to improve the quality of the remaining trees.

For the purposes of the forest management planning process in Ontario (OMNR 1996), spacing includes pre-commercial thinning and improvement cutting. Commercial thinning is addressed as a harvest method in this guide (see page 18).

**Improvement cutting** is an uneven-aged management treatment not generally used in the Boreal Forest of Ontario.

**Pre-commercial thinning (PCT)** is thinning that does not yield trees of commercial value, usually designed to improve crop spacing. In Ontario the term pre-commercial thinning is generally used in reference to even-aged management only (OMNR 1996). It is also referred to as 'thinning to waste' or 'early stocking control' (Oliver and Larson 1990).

Terms used to classify specific pre-commercial thinning activities generally refer to selection criteria (e.g. low thinning, crown thinning, selection thinning), or methods employed (e.g. mechanical thinning, row thinning, chemical thinning) (Smith 1986, NRC 1995).

Consider the following in developing a prescription for a thinning treatment (Oliver and Larson 1990):

- future product value (Bell *et al*. 1990)
- rate of volume growth
- removal of diseased, poorly formed, or undesirable stems
- future wood quality (Willcocks and Bell 1995)
- vigor of the remaining stand
- long-term sustainable harvest
- stand structure for non-timber uses (e.g. animal habitat, recreation)

**Black spruce thinning** is not widely used in Ontario, as upland black spruce stands are seldom overstocked, and thinning lowland sites is not cost-effective. Where black spruce plantations have been thinned, the usual method is to leave trees with straight stems, healthy full crowns and single, long leaders (Lemon 1981).

**Jack pine thinning** is carried out most commonly in dense stands on high value sites in boreal Ontario. Costs are lowest in stands 10 to 15 years old (Riley 1973, Goble and Bowling 1993, Morris *et al.* 1994).

**Aspen thinning** is generally not recommended if fibre production is the goal (Peterson and Peterson 1992). Aspen self-thins very effectively (Berry and Stiell 1978). If the intent is to increase the yield of large diameter products or product value, pre-commercial thinning aspen stands could be beneficial (Perala 1978). Both mechanical strip thinning and motor-manual spacing using brush saws are effective (Steneker 1974, Perala and Laidly 1989).

If considering thinning aspen stands, the cost and the potential for defect and decay should be weighted against the benefits of increased sawlog and veneer volume production (Perala 1978, Perala and Laidly 1989, Weingartner and Doucet 1990, Peterson and Peterson 1992).

## Pruning

Pruning is the removal of lower branches from standing live trees by natural or artificial means (NRC 1995). It is generally done when the desired end product is of high value (e.g. veneer logs). Pruning can also be done to improve aesthetics and interior access to a stand. When pruning, apply the treatment shortly after thinning operations (Lancaster 1984). For more information on pruning, refer to *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* (OMNR 1997b).

## Amelioration

Amelioration is any operation carried out on the physical site to change one or more abiotic factors in order to improve the growth or quality of a stand. It usually involves fertilization and/or drainage improvements.

**Fertilization** is the application of inorganic or organic fertilizers with the objective of increasing the unit area soil productivity (NRC 1995). It is not currently practised in Ontario, but it has been studied, with few definitive answers existing at this time. Foster *et al.* (1986) found a significant increase in diameter growth with nitrogen fertilizer applied to a black spruce stand on an imperfectly drained silty sand site. Payandeh (1989) had a significant diameter growth increase after NPK fertilizer application to a peatland spruce stand.

**Drainage** as an amelioration technique is not an operational practice in Ontario, but is under development (Haavisto and Wearn 1987). Drainage is widely used in Europe, especially Scandinavia. Drainage can lower water tables and increase growth rates. In one study in Alberta, volume yield increased fivefold in a drained spruce stand (Hillman 1987). Drainage may be most appropriate for productive black spruce stands on organic soils.

# Forest Health

The general health of Ontario's black spruce, jack pine and aspen forest has been monitored through a system of plots established and maintained by the Canadian Forest Service in co-operation with MNR. Information has been published detailing information collected through the acid rain early warning system (ARNEWS), and from the spruce-fir and the jack pine health plots.

Many species of insects and diseases affect black spruce, jack pine and aspen in Ontario. The majority of these are of minor importance and rarely reach epidemic proportions with subsequent tree mortality. Chapters 22 and 23 of the publication *Regenerating Ontario's Forests* (Colombo and Wagner in prep.) provide information on pests affecting immature stands. In this section we briefly discuss major insect pests and diseases that affect mature stands of black spruce, jack pine and aspen.

It may be appropriate to develop insect pest management strategies for certain species (e.g. spruce budworm, jack pine budworm) for inclusion in the forest management plan. This is especially important when an epidemic is ongoing or anticipated during the term of the plan. Such strategies may contribute to the achievement of both timber and non-timber objectives (OMNR 1996).

## Black Spruce

There are few serious insect pests of black spruce, but many minor ones. One of the most noticeable pests is the yellowheaded spruce sawfly (*Pikonema alaskensis*), which attacks all spruces. This can be very serious and has caused the failure of plantations. Stocking often has little effect on vulnerability. Control with insecticide can be warranted in severe infestations. These sawflies are attracted to young spruce, at least three to five years old and less than eight metres tall. If severe infestations last for two or more years, trees will suffer top kill or mortality (Hiratsuka *et al*. 1995).

Black spruce is not the preferred host of spruce budworm (*Choristoneura fumiferana*), but trees can be damaged during outbreaks of this pest when grown in association with balsam fir and white spruce. For more information on managing this insect, consult *Spruce Budworm Management Strategy for Ontario* (OMNR 1988). Reduced growth is common, although some tree mortality can also occur. Where damage is severe, spraying may be warranted.

Black spruce is prone to dwarf mistletoe (*Arceuthobium pusillum*), a parasitic plant from the Viscaceae family. This plant can also infect white and red spruce, and larch. Dwarf mistletoe causes witches brooms with consequent lower growth rates, poor wood quality and eventual mortality. Control measures include clearcutting infected areas along with a 10 to 40 m wide buffer zone. Slash should be burned and the area inspected 10 years later for residual infection. Ensuring that new stands are fully stocked will reduce the risk of infection and rate of spread from dwarf mistletoe. Infected trees can be removed during stand thinnings (Davis and Meyer 1997).

A common disease of black spruce is tomentosus root rot (*Inonotus tomentosus = Polyporus tomentosus*). It also attacks white spruce, balsam fir, and white, red and jack pine. This disease is most prevalent on well-drained, upland sites. Tomentosus root rot causes reduced vigour and butt rot, resulting in eventual windthrow. It can also increase the tree's susceptibility to other pests and abiotic factors. Infected stands can be clearcut and planted with less susceptible species, or can be regenerated as mixedwood stands with conifers and broadleaf species. Thinning young stands will reduce the incidence of infection (Davis and Meyer 1997). Avoiding spruce monocultures on replanted upland sites is probably the best method for minimizing future losses to this disease.

Armillaria root rot (*Armillaria* spp.) is a very common fungus found in many forest ecosystems. It can attack weakened individuals of most conifer and hardwood species, including black spruce, jack pine and aspen. A single genetic individual can cover several hectares and live for hundreds to thousands of years. Management of this disease is rarely undertaken in Ontario, and is only feasible at the harvesting and stand establishment stages. Preharvest inspections are needed to determine mortality centres, identified as gaps in younger stands with woody shrubs, and in older stands as randomly spaced, dead trees broken off at ground level. Root removal in these areas is recommended (Davis and Meyer 1997) as the larger roots represent a threat to the next stand. The best method of managing this disease and reducing losses from tree mortality is to minimize stand stress from silvicultural activities and other factors such as insect attack (Davis and Meyer 1997).

Velvet top fungus (*Phaeolus schweinitzii*) attacks black and white spruce, balsam fir, and occasionally white and jack pine, and rarely larch and hemlock. This fungus is associated with older stands, as the incidence of infection increases with stand age. Managers need to balance economic rotation, volume losses and increased inoculum potential of the site with losses from velvet top fungus. Prevention of decay is the easiest way to manage this disease, as it behaves similar to other wound-requiring fungi. It is necessary to minimize wounding trees during tending and partial cutting operations. Preharvest surveys should be done to provide information on the amount of infection within a stand and future potential for this disease. Only in extreme cases are measures such as root removal needed for control of this disease (Davis and Meyer 1997).

## Jack Pine

Examples of important species attacking young jack pine are the white pine weevil (*Pissodes strobi*), European pine shoot moth (*Rhyacionia buoliana*), and numerous sawfly species (e.g. *Diprion* spp, *Neodiprion* spp). Control of these insects is often warranted for young trees using registered and approved insecticides when required. Sawfly damage may also be severe in mature jack pine.

Jack pine budworm (*Choristoneura pinus pinus*) is the main insect pest of mature jack pine. It can reach epidemic proportions and cause widespread mortality, top kill, multiple leaders and crooked tops. Outbreaks can last two to four years and can re-occur at irregular intervals (compared to the ten year cycle in the prairie provinces). Severe defoliation for two or more consecutive years will result in top kill and tree mortality. Vulnerability to attack is influenced by root condition. For example, root diseases, deformities (such as from poor planting techniques), root disturbance, and drought stress increase the risk of attack from this insect. Overmature stands and stands on the best quality sites are especially vulnerable to attack (Rose and Lindquist 1973, Hiratsuka *et al*. 1995).

Insecticides can be used to reduce damage caused by jack pine budworm during outbreaks. With the characteristic rapid rise and collapse of budworm populations during outbreaks, and the ability of the insect to cause permanent damage even in the first year of defoliation, it is important to monitor jack pine budworm populations and to conduct control measures as early as possible in the outbreak. Salvage harvesting, rescheduling of harvest to affected stands, maintaining basal area, and reducing the amount of stand edge or male flowering, can also be used to reduce losses and damage caused by jack pine budworm.

A serious disease of jack pine is scleroderris canker (*Gremmeniella abietina*). It affects young trees but rarely kills trees over two metres tall. It also attacks the other pine species found in Ontario. Pruning infected whorls is the ideal method of control at the stand establishment phase. If more than two percent of trees in a plantation are infected, pruning of all trees up to one whorl above the highest infected branch is recommended. If more than 60 percent of the branches on a tree are infected, the tree should be cut and burned. If over 25 percent of the trees in a plantation are affected, the plantation should be cut and burned (Davis and Meyer 1997).

Other diseases of jack pine include armillaria root rot, tomentosus root rot and velvet top fungus. These diseases have been discussed previously under black spruce.

## Aspen

There are dozens of insect species that attack aspen, but we will only discuss two species in this section. Forest tent caterpillar (*Malacosoma disstria*) is the best known and most prevalent species that attacks aspen and many other broadleaf species. Periodically it will reach epidemic numbers and can cause widespread and severe defoliation of entire stands. Control using aerial spraying of insecticides may be effective in reducing damage caused by forest tent caterpillar. One or more years of severe defoliation may result in twig and branch mortality, reduced volume growth and smaller leaf size. Mortality does occur, although growth loss is more common. Trees suffering more than 50 percent defoliation will usually refoliate in the same growing season, but this can be an added stress to the trees. Any mortality that does occur is usually in conjunction with site-based factors and stresses such as drought, late spring frost or previous defoliations by other insects. Defoliated trees are more susceptible to secondary attack from cankers, wood decay fungi, and stem and wood boring insects (Rose and Lindquist 1982, Hiratsuka *et al*. 1995).

Another major species that attacks aspen is the large aspen tortrix (*Choristoneura conflictana*). It is widespread and can reach epidemic proportions. It rolls and fastens one or more leaves with silk and mines the leaf tissue. Severe defoliation can cause radial growth loss, but little mortality. When infected in combination with other stress factors and other defoliators, the trees become more susceptible to attack from cankers, wood decay fungi, and stem and wood boring insects, similar to effects from forest tent caterpillars (Rose and Lindquist 1982, Hiratsuka *et al*. 1995). There are other defoliating insects of aspen that periodically reach outbreak proportions, such as the aspen twoleaf tier (*Enargia decolor*).

Hypoxylon canker (*Hypoxylon mammatum*) is a serious problem in aspen stands. It forms stem cankers that weaken the stem, causing stem breakage from wind, or it can eventually girdle the stem and kill the tree. The disease is more common in low density aspen stands and on stressed trees suffering from stem and branch injuries. In intensively managed stands, efforts need to be made to minimize wounding of trees or suckers during any management activity. Diseased trees can be removed during stand thinnings (Davis and Meyer 1997).

# Genetic Resources

The objectives of genetic resource management include both the conservation and use of genetic diversity. Genetic diversity is generally accepted as the ultimate source of species and ecosystem diversity. Consequently, the long term goal for gene conservation is to maintain the evolutionary capacity of native species. In addition, genetic diversity also provides the raw material for economically driven tree improvement programs. (Joyce *et al.* in prep.)

Tree improvement programs are directed at improving the productivity and quality of commercial forest tree species and are integral to any silviculture program. Strategies for realizing genetic improvements are varied and reflect local choices and responses to geographic, technical, economic and political factors (Yeatman 1984). Programs may involve various levels of intensity from seed source control, seed collection areas, seed production areas, seed orchards and progeny testing (Morgenstern 1979).

Improvement programs for jack pine, black spruce and trembling aspen have developed as follows (OMNR 1987):

a) Individual tree characteristics affecting wood quality and fibre yield are under strong genetic influence for jack pine. The basis for improvement for jack pine is the high level of genetic variability from tree to tree as is clearly evident from family and clonal testing (Yeatman 1984).

   In Ontario, the open-pollinated seedling seed orchard approach was used for the first generation improvement program for jack pine (OMNR 1987). Seed was collected from "plus trees" and used to establish seed orchards and test sites. Based primarily on the measurement of height growth in the test sites, the poorest performing families in the orchards are scheduled to be removed or 'rogued'. The remaining families in the orchard cross-pollinate and provide the "improved" seed to support artificial regeneration programs.

b) Genetics research has indicated that black spruce is variable in quantitative traits such as height and diameter, and improvement by breeding and selection is promising (Arnup *et al.* 1988).

   An open-pollinated seedling seed orchard approach was also chosen for black spruce due to its precocious and prolific flowering habit, among other factors (OMNR, 1987). Twenty-four seed orchards have been established across the province, many of which have received at least one roguing (i.e. are producing genetically improved seed) (Joyce *et al.* in prep.). In some areas of the Province, there is sufficient seed production in the seed orchards to provide for the entire operational planting program.

c) For aspen, the asexual mode of regeneration by root suckering causes aspen stands to develop as mosaics of clones with each sucker (ramet) having the same genotype as the original stem (ortet). Genetic variation between clones has been reported for a number of characteristics, including tree form, response to frost, growth and defect, patterns of height growth, suckering and rooting ability, susceptibility to hypoxylon canker, and wood specific gravity and fibre length (Davidson *et al.* 1988).

> Genetic improvement of the aspens is currently a low priority in Ontario, primarily because trembling aspen obtains excellent natural regeneration by suckering. Other reasons include the poor rootability of aspen cuttings, and the small demand for planting stock (Davidson *et al.* 1988).

Provenance testing has shown that tree species exhibit genetic diversity across their range. Critical genetic differences with respect to attributes such as winter hardiness, susceptibility to disease, and growth are associated with seed origin and climate. Populations have differentiated and adapted to the regional climates in which they occur through processes of natural selection, migration and isolation.

When seedlings are moved some distance from their geographic origin, they are usually poorly adapted to the local climatic conditions.

Poorly adapted trees are at an increased risk of growing under stress or of undergoing repeated damage and even death due to cold, drought, insects and disease. The advantages of artificial regeneration (e.g. the control of spacing with attendant reduction in rotation period) will only be maintained when well adapted and fast-growing trees are established (Morgenstern 1975, Yeatman 1984). Therefore, regulation of seed collection, distribution, and identification, as well as the designation of natural populations for seed production and gene conservation are key components of successful regeneration programs (Wang and Fogal 1979, Yeatman and Morgenstern 1979).

Seed zones have been derived using elevation and climate models to reduce the risk of using maladapted seed in artificial regeneration programs (Joyce 1995, Parker 1995b, 1996). Seed and planting stock must be used in the seed zone in which it originated, unless testing has shown that transfers are acceptable (OMNR 1997c). Genecology studies in northwestern Ontario have resulted in the development of “focal point” seed zones which may be used to more accurately describe seed collection areas and guide the deployment of seed in artificial regeneration programs (Parker 1995b, 1996).

A thorough overview of genetic resource management principles and practices, including the impact of silviculture practices on the genetic resource, is presented in *Forest Genetic Resources: Management Principles and Practices* (Joyce *et al.* in prep.) in *Regenerating Ontario’s Forests* (Colombo and Wagner in prep.).

# *Section III*

## Autecology of Selected Forest Plants

Autecology is the branch of ecology dealing with the study of the responses and adaptations of individual species or populations to their environment (Barbour *et al*. 1987). The work of Haeussler and Coates (1986) was the first comprehensive literature review of the autecological characteristics of forest plant species that compete with conifers in British Columbia. Their work has inspired five similar literature reviews (Sims *et al.* 1990, Bell 1991, Louter *et al.* 1993, Bentley and Pinto 1994, Bell and Kershaw 1997) and two autecology guides of Ontario's forest plants (Buse and Bell 1992, Arnup *et al.* 1994). These publications include information on eight conifer, 85 deciduous tree and shrub, 27 herb, 17 graminoid, three fern, three lichen, three moss, and seven sphagnum species found in Ontario.

The species selected for presentation in this chapter are trees, shrubs and herbs found in the Boreal Forest region of Ontario. Common and scientific names are consistent with current names used in Ontario (Newmaster *et al.* 1997) (**Table 1**). In each table, species are grouped by life form and then listed alphabetically by scientific name. Their nomenclature, growth habit, reproductive characteristics, phenology, ecophysiology and response to disturbance have been summarized in eleven tables. Although not provided in this chapter, brief written taxonomic descriptions of stems, leaves, flowers and fruits accompanied by an illustration of each species are available in Legasy *et al.* (1995) and Baldwin and Sims (1997).

Methods to control or promote the growth of a species should be based on growth habit, reproductive characteristics, environmental requirements and competitive status.

Growth habit determines relative competitiveness in a forest community, and includes:

- life cycle
- longevity
- growth pattern

Plants have one of three life cycles. Plants may be annuals, biennials, or perennials and complete their life cycles within one, two and more than two growing seasons respectively. Annuals and biennials rarely constitute a serious obstacle to conifer regeneration because of their short life span. They may temporarily reduce height growth or smother (through snow load or leaf litter) small conifer seedlings.

The longevity of perennial plant species can contribute to their competitive status. Long lived species (e.g. white spruce and cedar) generally outcompete short-lived species (e.g. hazel and raspberry) unless the short-lived species are more successful competitors. Perennials (e.g. trees, shrubs, and most persistent herbs) also often create greater competition because of their rapid regrowth following a disturbance. All species presented in **Table 1** are perennials.

Growth patterns (e.g. stem height, clone size, rooting zone and root grafting) also contribute to a plant's competitive status. For example, the maximum height that a species can achieve will determine if it will be a competitor for a few years or for many years. Root grafting permits subordinate plants to obtain nutrients from dominant plants.

The regional forest ecosystem classifications provide quantitative information on the relationships between vegetation and site characteristics that can be used to help predict the occurrence of various plant species, and identify the most important competitive species, on a given ecosite or site type. This information, combined with knowledge of the moisture, nutrients and light requirements of a plant species, can be used to tailor silvicultural practices to promote or retard the growth of selected species. Information on the frequency of occurrence of selected species is presented for northwestern Ontario forest ecosystem classification vegetation types (**Table 2**) and northeastern Ontario site types (**Table 3**).

The tables should only be considered as guides. Natural variability that characterizes forests throughout northern Ontario accounts for species that are not listed for specific vegetation or site types and still may occur. In addition, since data collection was directed at mature forest ecosystems, the tables do not necessarily indicate species distributions in non-forested or disturbed habitats.

Plant species with high reproductive capabilities are more difficult to control and easier to promote than species with limited reproductive capabilities. Almost all plants reproduce both vegetatively and sexually (**Tables 4** and **5**).

Vegetative reproduction can occur through root suckers, rhizomes, root collar and stem sprouts, and layers. Vegetative reproduction is generally more important than sexual reproduction in the rapid recovery of plant cover immediately following a disturbance. For example, sprouting from suckers connected to parent plants with established food reserves and water supply (Zasada 1971) facilitates regrowth of site-adapted individuals without depending on seed supply, dispersal and viability, or seedbed conditions.

Sexual reproduction can be broken into three categories: reproductive characteristics, seed dispersal characteristics, and seed germination requirements. Reproductive characteristics include reproduction class (monoecious, dioecious or perfect), propagule type, minimum seed bearing age, periodicity of large seed crops and seedling regeneration strategy (**Table 5**). Potential seed production for each species ranges from hundreds to millions of seeds per plant per year. Those species that reach sexual maturity and produce large amounts of seed early in their life cycle have a competitive advantage over species that first produce seeds at older ages (Zasada 1988). Although annual reproductive potential is rarely realized for any given species, total failures seldom occur (Zasada 1988). Plant species which are seemingly rare or absent in mature forest stands may become established from buried seeds and quickly dominate the pioneer vegetation community following timber harvest, fire or other major disturbance. Seed bank species composition and seed densities will vary greatly from site to site (Kramer and Johnson 1987). While it is possible to eradicate species with short-lived seeds using control strategies that eliminate seed production, this is not a feasible strategy with species having long-lived seeds. Knowledge of seed longevity in the soil helps to predict weed population dynamics (Conn and Farris 1987) and develop integrated vegetation management plans. For a comprehensive review of the sexual reproductive characteristics of plant species refer to Schopmeyer (1974) and Young and Young (1992).

Factors affecting seed dispersal include seed type and size, time of seed ripening (phenology) and distance and mode of dispersal (**Table 6**). Seed type and size directly affect seed dispersion. For example, small winged seeds are capable of travelling several kilometres. Successful regeneration is often dependent upon seed arrival coinciding with a disturbance (i.e. suitable seedbed and microenvironmental conditions), as many wind-borne seeds have a limited period of viability and new seedlings cannot compete with extensive competition from established plants (Marks 1974). Seeds are dispersed by wind, water, gravity, mammals and birds, each influencing the distance travelled from the parent plant.

Regeneration from seed requires the dispersal of abundant viable seed to microsites, or seedbeds, that provide the environmental conditions and resources needed to support germination and establishment (Farmer 1996) (**Table 7**). The seed of most forest tree species has physiological or physical dormancy at time of dispersal that must be overcome before germination can occur. Following exposure to the appropriate conditioning environment (e.g. chilling requirement) dormancy is broken and seed germination is dependent on moisture, temperature and aeration. Within a species, the degree of dormancy and temperature regime for optimal germination varies with provenance. Seed viability also varies among individuals, within individuals from year-to-year and is typically higher during heavy seed crops.

Following establishment, the microsite must provide young seedlings with sufficient water, nutrients and light to support a competitive growth rate. The microsite must also be free of competition, fire, pathogens, insects, etc. Failure to obtain resources adequate to support normal levels of physiological activity can reduce growth and survival. Resource limitations may result from climatic events, (e.g. drought, flooding) site limitations (e.g. infertility) and competition with neighboring vegetation (e.g. shading). Tree species vary widely in their capacity to tolerate and adapt to environmental stresses and resource limitations. Knowledge of species resource requirements and their tolerance to environmental stress is useful in planning of forest management activities to favor the growth of crop species (**Table 8**).

Table 1. Form, longevity and growth habit of selected species.

| | Common Name | Scientific Name | Longevity (yrs) | Maximum Stem Height (m) | Maximum Area of Clone ($m^2$) | Zone of Rooting | Forms Root |
|---|---|---|---|---|---|---|---|
| Trees | balsam fir | *Abies balsamea* | 150 | 25 | — | Org/Min | — |
| | red maple | *Acer rubrum* | 150 | 30 | — | Mineral | yes |
| | sugar maple | *Acer saccharum* | 300 – 400 | 39 | — | Mineral | yes |
| | yellow birch | *Betula alleghaniensis* | 300 – 350 | 30 | — | Mineral | — |
| | white birch | *Betula papyrifera* | 140 | 28 | 1 | Mineral | — |
| | black ash | *Fraxinus nigra* | 250 – 300 | 18 – 21 | — | — | — |
| | larch | *Larix laricina* | 150 – 180 | 30 – 35 | — | Org/Min | — |
| | white spruce | *Picea glauca* | 250 – 300 | 34 | — | Mineral | — |
| | black spruce | *Picea mariana* | 250+ | 25 | — | Org/Min | yes |
| | red spruce | *Picea rubens* | 400 | 18 – 23 | — | Org/Min | — |
| | jack pine | *Pinus banksiana* | 200+ | 30 | — | Mineral | — |
| | red pine | *Pinus resinosa* | 200+ | 34 | — | Mineral | yes |
| | white pine | *Pinus strobus* | 300+ | 38 | — | Mineral | yes |
| | balsam poplar | *Populus balsamifera* | 200 | 30 | — | Mineral | — |
| | largetooth aspen | *Populus grandidentata* | 80 – 100 | 18 – 24 (30) | — | Mineral | — |
| | trembling aspen | *Populus tremuloides* | 120 | 34 | 965,000 | Mineral | — |
| | red oak | *Quercus rubra* | 125 – 150 | 30 | — | Mineral | — |
| | mountain ash | *Sorbus* spp. | — | 10 | — | Min/Org | — |
| | eastern white cedar | *Thuja occidentalis* | 400 – 500 | 21 – 24 | — | Org/Min | — |
| | eastern hemlock | *Tsuga canadensis* | 500+ | 49 | — | Mineral | yes |
| | American elm | *Ulmus americana* | 300 | 38 | — | Mineral | — |

Table 1 (con't). Form, longevity and growth habit of selected species.

| | Common Name | Scientific Name | Longevity (yrs) | Maximum Stem Height (m) | Maximum Area of Clone ($m^2$) | Zone of Rooting | Forms Root Grafts |
|---|---|---|---|---|---|---|---|
| Shrubs | mountain maple | *Acer spicatum* | — | 3 | 2 | Organic | no |
| | speckled alder | *Alnus incana* ssp. *rugosa* | — | 4 | — | Min/Org | — |
| | green alder | *Alnus viridis* ssp. *crispa* | — | 3 | — | Mineral | — |
| | serviceberry | *Amelanchier* spp. | 40 | 7 | — | Min/Org | — |
| | bog rosemary | *Andromeda glaucophylla* | — | 0.5 | — | Organic | — |
| | bearberry | *Arctostaphylos uva-ursi* | — | 0.15 | 12 | Min/Org | — |
| | swamp birch | *Betula pumila* | — | 2 | — | Organic | — |
| | leatherleaf | *Chamaedaphne calyculata* | — | 1 | — | Organic | — |
| | sweetfern | *Comptonia peregrina* | — | 1 | — | Mineral | — |
| | red osier dogwood | *Cornus stolonifera* | — | 2 | — | Mineral | — |
| | beaked hazel | *Corylus cornuta* | 60 | 3 | 2 | Organic | — |
| | bush honeysuckle | *Diervilla lonicera* | — | 1 | — | Mineral | — |
| | sheep laurel | *Kalmia angustifolia* | — | 1 | — | Min/Org | — |
| | bog laurel | *Kalmia polifolia* | — | 0.6 | — | Min/Org | — |
| | Labrador-tea | *Ledum groenlandicum* | — | 1 | 10 | Organic | — |
| | honeysuckles | *Lonicera* spp. | — | 3 | — | Min/Org | — |
| | fly honeysuckle | *Lonicera villosa* | — | 1 | — | Organic | — |
| | pin cherry | *Prunus pensylvanica* | 30 | 5 | — | Mineral | — |
| | choke cherry | *Prunus virginiana* | — | 4 | — | Mineral | — |
| | currants | *Ribes* spp. | — | 3 | — | Mineral | — |
| | wild prickly rose | *Rosa acicularis* | — | 1 | — | Mineral | — |

Table 1 (con't). Form, longevity and growth habit of selected species.

| | Common Name | Scientific Name | Longevity (yrs) | Maximum Stem Height (m) | Maximum Area of Clone (m²) | Zone of Rooting | Forms Root Grafts |
|---|---|---|---|---|---|---|---|
| Shrubs | wild raspberry | *Rubus idaeus* var. *strigosus* | — | 2 | 20 | Mineral | — |
| | willows | *Salix* spp. | 40+ | 1 – 6 | — | Org/Min | — |
| | red elderberry | *Sambucus pubens* | — | 4 | — | Min/Org | — |
| | low sweet blueberry | *Vaccinium angustifolium* | 150 | 0.5 | — | Org/Min | — |
| | velvetleaf blueberry | *Vaccinium myrtilloides* | — | 0.5 | 300+ | Org/Min | — |
| | viburnum | *Viburnum* spp. | — | 2 | — | Mineral | — |
| Other | large-leaved aster | *Aster macrophyllus* | — | 1 | — | Mineral | — |
| | blue-joint grass | *Calamagrostis canadensis* | — | 1 – 2 | — | Min/Org | — |
| | sedges | *Carex* spp. | — | 1 | — | Min/Org | — |
| | field bindweed | *Convolvulus arvensis* | — | — | — | Mineral | — |
| | fireweed | *Epilobium angustifolium* | 20+ | 2 | — | Mineral | — |
| | grasses | Poaceae | — | 1 | — | Min/Org | — |
| | bracken fern | *Pteridium aquilinum* | 100 | 1 – 2 | — | Org/Min | no |

Table 2. Frequency of occurrence of selected plant species by NWO FEC vegetation type.

| | Common Name | Vegetation Types | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mainly Hardwoods | | | | | | | | | | Conifer Mixedwoods | | | | | | | | | | Conifer | | | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
| Trees | balsam fir | 76-100 | 76-100 | 26-50 | 76-100 | 51-75 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 51-75 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 51-75 | 76-100 | 26-50 | 76-100 | 76-100 | 51-75 | 76-100 | 76-100 | 76-100 | 76-100 | 51-75 | 26-50 | 26-50 | 76-100 | 26-50 | 26-50 | 51-75 | 51-75 | 51-75 | 1-25 | 1-25 |
| | white birch | 26-50 | 26-50 | 1-25 | 51-75 | 51-75 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 51-75 | 26-50 | 26-50 | 51-75 | 51-75 | 51-75 | 26-50 | 51-75 | 26-50 | 1-25 | 1-25 | 26-50 | 26-50 | 26-50 | 51-75 | 51-75 | 26-50 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 |
| | white spruce | 26-50 | 51-75 | 26-50 | 26-50 | 1-25 | 26-50 | 26-50 | 51-75 | 76-100 | 26-50 | 26-50 | 26-50 | 1-25 | 26-50 | 76-100 | 76-100 | 26-50 | 1-25 | 1-25 | 1-25 | 51-75 | 1-25 | 1-25 | 76-100 | 76-100 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 1-25 | 1-25 | 1-25 | Absent | Absent | Absent | Absent |
| | black spruce | 26-50 | 1-25 | Absent | 51-75 | 26-50 | 1-25 | 26-50 | 51-75 | 26-50 | 76-100 | 76-100 | 1-25 | 26-50 | 26-50 | 26-50 | 51-75 | 51-75 | 76-100 | 76-100 | 76-100 | 1-25 | 76-100 | 76-100 | 26-50 | 51-75 | 1-25 | 51-75 | 26-50 | 51-75 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 |
| | jack pine | 1-25 | Absent | Absent | 26-50 | 1-25 | 1-25 | 1-25 | 26-50 | 26-50 | 51-75 | 51-75 | 1-25 | 26-50 | 1-25 | 1-25 | 26-50 | 76-100 | 76-100 | 26-50 | 51-75 | Absent | Absent | 1-25 | 1-25 | 26-50 | 1-25 | 26-50 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | Absent |
| | red pine | Absent | Absent | Absent | Absent | 1-25 | Absent | Absent | Absent | Absent | 1-25 | Absent | 26-50 | 76-100 | 1-25 | Absent | Absent | 1-25 | 1-25 | Absent | Absent | Absent | Absent | Absent | Absent | 1-25 | 26-50 | 76-100 | Absent | Absent | Absent | Absent | Absent | 1-25 | Absent | Absent | 1-25 | Absent | Absent |
| | white pine | Absent | Absent | Absent | Absent | Absent | Absent | 1-25 | 1-25 | 1-25 | Absent | Absent | 76-100 | 26-50 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | Absent | 1-25 | 1-25 | Absent | Absent | Absent | Absent | 76-100 | 1-25 | 1-25 | Absent | Absent | Absent | Absent | 1-25 | Absent | Absent | Absent | Absent | Absent |
| | balsam poplar | 51-75 | 1-25 | Absent | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | Absent | Absent | Absent | 1-25 | Absent | 1-25 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | Absent |
| | trembling aspen | 26-50 | 1-25 | Absent | 1-25 | 51-75 | 76-100 | 51-75 | 51-75 | 51-75 | 51-75 | 51-75 | 51-75 | 1-25 | 51-75 | 26-50 | 26-50 | 51-75 | 26-50 | 51-75 | 1-25 | 26-50 | Absent | Absent | 26-50 | 1-25 | 1-25 | 26-50 | 26-50 | 1-25 | 1-25 | 26-50 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | Absent |
| Shrubs | mountain maple | 51-75 | 76-100 | 51-75 | 51-75 | 51-75 | 76-100 | 51-75 | 76-100 | 51-75 | 1-25 | 1-25 | 76-100 | 51-75 | 76-100 | 51-75 | 51-75 | 26-50 | 1-25 | 26-50 | 1-25 | 76-100 | 26-50 | 1-25 | 51-75 | 26-50 | 51-75 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | Absent | Absent |
| | speckled alder | 51-75 | 51-75 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 1-25 | 26-50 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 1-25 | 1-25 | 76-100 | 76-100 | 26-50 | 1-25 | Absent | Absent | Absent | Absent | Absent | 1-25 | 1-25 | 1-25 | 51-75 | 76-100 | 26-50 | 1-25 | 1-25 |
| | green alder | 1-25 | Absent | 1-25 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 26-50 | 51-75 | 26-50 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 51-75 | 26-50 | 26-50 | 26-50 | Absent | Absent | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 26-50 | 26-50 | 1-25 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 |
| | serviceberry | 51-75 | 26-50 | 26-50 | 51-75 | 51-75 | 26-50 | 26-50 | 51-75 | 51-75 | 51-75 | 26-50 | 51-75 | 26-50 | 26-50 | 51-75 | 26-50 | 51-75 | 26-50 | 51-75 | 1-25 | 26-50 | 26-50 | 26-50 | 76-100 | 51-75 | 51-75 | 26-50 | 76-100 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 26-50 | 1-25 | Absent |
| | red osier dogwood | 51-75 | 51-75 | 1-25 | 1-25 | 26-50 | 1-25 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 51-75 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 1-25 | Absent | Absent |
| | beaked hazel | 26-50 | 26-50 | 51-75 | 26-50 | 76-100 | 51-75 | 51-75 | 76-100 | 76-100 | 26-50 | 1-25 | 76-100 | 51-75 | 51-75 | 51-75 | 26-50 | 51-75 | Absent | 1-25 | 1-25 | 26-50 | 1-25 | 1-25 | 51-75 | 26-50 | 51-75 | 26-50 | 51-75 | 1-25 | 1-25 | 26-50 | 1-25 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | Absent |
| | Labrador-tea | 1-25 | 1-25 | Absent | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 26-50 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 1-25 | 26-50 | 51-75 | 51-75 | 1-25 | 76-100 | 76-100 | 1-25 | 1-25 | Absent | 1-25 | 1-25 | 26-50 | 26-50 | 26-50 | 51-75 | 51-75 | 76-100 | 76-100 | 76-100 | 76-100 | 76-100 |

Absent  1 - 25%  26 - 50%  51 - 75%  76 - 100%

Table 2 (con't). Frequency of occurrence of selected plant species by NWO FEC vegetation type.

| | Common Name | Vegetation Types | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mainly Hardwoods | | | | | | | | | | Conifer Mixedwoods | | | | | | | | | | Conifer | | | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
| Shrubs | pin cherry | 1 - 25% | Absent | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent | Absent | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent | Absent | Absent | Absent | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent | Absent | 1 - 25% | Absent | Absent |
| | choke cherry | 26 - 50% | 51 - 75% | 76 - 100% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent |
| | currants | 76 - 100% | 76 - 100% | 76 - 100% | 26 - 50% | 26 - 50% | 26 - 50% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 51 - 75% | 26 - 50% | 26 - 50% | 1 - 25% | 26 - 50% | Absent | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | Absent | Absent |
| | wild prickly rose | 76 - 100% | 1 - 25% | 26 - 50% | Absent | 51 - 75% | 26 - 50% | 51 - 75% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | Absent | 26 - 50% | 51 - 75% | 26 - 50% | 51 - 75% | 26 - 50% | 51 - 75% | 1 - 25% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 1 - 25% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | Absent | Absent |
| | wild raspberry | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | Absent |
| | willows | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% |
| | low sweet blueberry | 1 - 25% | 1 - 25% | 1 - 25% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 1 - 25% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 76 - 100% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% | 51 - 75% |
| | velvetleaf blueberry | 1 - 25% | 1 - 25% | 1 - 25% | 51 - 75% | 26 - 50% | 1 - 25% | 26 - 50% | 26 - 50% | 26 - 50% | 51 - 75% | 76 - 100% | 26 - 50% | 51 - 75% | 26 - 50% | 1 - 25% | 51 - 75% | 26 - 50% | 76 - 100% | 51 - 75% | 51 - 75% | 1 - 25% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 51 - 75% | 51 - 75% | 76 - 100% | 51 - 75% | 51 - 75% | 26 - 50% |
| Other | large-leaved aster | 51 - 75% | 26 - 50% | 76 - 100% | 1 - 25% | 26 - 50% | 26 - 50% | 51 - 75% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 51 - 75% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% |
| | blue-joint grass | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | Absent |
| | sedges | 51 - 75% | 76 - 100% | 76 - 100% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 51 - 75% | 76 - 100% | 51 - 75% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 51 - 75% | 76 - 100% | 76 - 100% | 51 - 75% | 76 - 100% |
| | fireweed | 26 - 50% | 1 - 25% | Absent | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% |
| | bracken fern | 1 - 25% | Absent | Absent | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | Absent | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | Absent | Absent |

Absent | 1 - 25% | 26 - 50% | 51 - 75% | 76 - 100%

Table 3. Frequency of occurrence of selected plant species by NE-FEC site type.

| | Common Name | Shallow Soils | Coarse Soils | | | | | Fine Soils | | | | | | | Shallow Organic Soils | | | Deep Organic Soils | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2a | 2b | 3a | 3b | 4 | 5a | 5b | 6a | 6b | 6c | 7a | 7b | 8 | 9 | 10 | 11 | 12 | 13 |
| Trees | balsam fir | 51 - 75% | 51 - 75% | 51 - 75% | 76 - 100% | 76 - 100% | 51 - 75% | 51 - 75% | 51 - 75% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 51 - 75% | 76 - 100% | 76 - 100% | 51 - 75% | 51 - 75% | 76 - 100% |
| Trees | red maple | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent | 1 - 25% | Absent | 1 - 25% | Absent | Absent | Absent | Absent | 1 - 25% | Absent | Absent | Absent | Absent |
| Trees | sugar maple | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent |
| Trees | yellow birch | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent |
| Trees | white birch | 51 - 75% | 1 - 25% | 26 - 50% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 1 - 25% | 26 - 50% | 51 - 75% | 76 - 100% | 51 - 75% | 76 - 100% | 1 - 25% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 26 - 50% |
| Trees | white spruce | 51 - 75% | 1 - 25% | 1 - 25% | 26 - 50% | 51 - 75% | 1 - 25% | Absent | Absent | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 51 - 75% | 1 - 25% | 26 - 50% | 51 - 75% | 1 - 25% | Absent | 1 - 25% |
| Trees | black spruce | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 76 - 100% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 76 - 100% | 76 - 100% | 51 - 75% | 76 - 100% | 76 - 100% | 76 - 100% |
| Trees | jack pine | 26 - 50% | 76 - 100% | 76 - 100% | 51 - 75% | 51 - 75% | 51 - 75% | 26 - 50% | 51 - 75% | 1 - 25% | 51 - 75% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent |
| Trees | red pine | Absent | Absent | 1 - 25% | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | 1 - 25% | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent |
| Trees | white pine | 1 - 25% | Absent | 1 - 25% | Absent | 1 - 25% | 1 - 25% | Absent | Absent | Absent | 1 - 25% | 1 - 25% | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent |
| Trees | trembling aspen | 1 - 25% | 1 - 25% | 1 - 25% | 76 - 100% | 76 - 100% | 1 - 25% | 1 - 25% | 1 - 25% | 51 - 75% | 51 - 75% | 76 - 100% | 76 - 100% | 76 - 100% | 1 - 25% | 1 - 25% | 76 - 100% | 1 - 25% | 1 - 25% | 1 - 25% |
| Trees | mountain ash | 51 - 75% | 1 - 25% | 1 - 25% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 1 - 25% | 51 - 75% | 76 - 100% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 51 - 75% | 26 - 50% | 1 - 25% | 26 - 50% | 51 - 75% |
| Trees | mountain maple | 26 - 50% | Absent | Absent | 1 - 25% | 26 - 50% | Absent | Absent | Absent | 1 - 25% | 26 - 50% | 76 - 100% | 51 - 75% | 76 - 100% | Absent | 26 - 50% | 26 - 50% | Absent | 1 - 25% | 1 - 25% |
| Shrubs | speckled alder | 1 - 25% | Absent | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 51 - 75% | 51 - 75% | 26 - 50% | 76 - 100% | 76 - 100% |
| Shrubs | green alder | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | 1 - 25% | Absent | Absent | Absent |
| Shrubs | serviceberry | 51 - 75% | 26 - 50% | 51 - 75% | 51 - 75% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 51 - 75% | 76 - 100% | 51 - 75% | 26 - 50% | 26 - 50% | 26 - 50% | 51 - 75% | 51 - 75% | 26 - 50% | 1 - 25% | 51 - 75% |
| Shrubs | bog rosemary | Absent | Absent | Absent | Absent | Absent | Absent | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent | 1 - 25% | Absent | Absent | 1 - 25% | 1 - 25% |
| Shrubs | bearberry | Absent | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent |
| Shrubs | swamp birch | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% |
| Shrubs | leatherleaf | 1 - 25% | Absent | Absent | Absent | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent | Absent | 1 - 25% | 1 - 25% | Absent | 51 - 75% | 26 - 50% | 1 - 25% |
| Shrubs | sweetfern | Absent | 1 - 25% | 1 - 25% | Absent | 1 - 25% | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent |
| Shrubs | red osier dogwood | 1 - 25% | Absent | Absent | Absent | 1 - 25% | 1 - 25% | 1 - 25% | Absent | 1 - 25% | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | Absent | 26 - 50% | 26 - 50% | 1 - 25% | 1 - 25% | 51 - 75% |
| Shrubs | beaked hazel | 26 - 50% | Absent | 1 - 25% | 1 - 25% | 26 - 50% | 1 - 25% | 1 - 25% | Absent | 26 - 50% | 26 - 50% | 76 - 100% | 51 - 75% | 51 - 75% | Absent | 1 - 25% | 26 - 50% | Absent | Absent | 1 - 25% |

Absent 1 - 25% 26 - 50% 51 - 75% 76 - 100%

Table 3 (con't). Frequency of occurrence of selected plant species by NE-FEC site type.

| | Common Name | Shallow Soils | Coarse Soils | | | | | Fine Soils | | | | | | | Shallow Organic Soils | | | Deep Organic Soils | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2a | 2b | 3a | 3b | 4 | 5a | 5b | 6a | 6b | 6c | 7a | 7b | 8 | 9 | 10 | 11 | 12 | 13 |
| Shrubs | bush honeysuckle | 26-50% | 26-50% | 26-50% | 76-100% | 76-100% | 26-50% | 1-25% | 1-25% | 51-75% | 51-75% | 76-100% | 51-75% | 76-100% | Absent | 1-25% | 26-50% | Absent | Absent | Absent |
| Shrubs | sheep laurel | 1-25% | 26-50% | 26-50% | 1-25% | 1-25% | 26-50% | 26-50% | 26-50% | 1-25% | 1-25% | Absent | Absent | Absent | 26-50% | 1-25% | 1-25% | 26-50% | 1-25% | 1-25% |
| Shrubs | bog laurel | 1-25% | Absent | Absent | Absent | Absent | Absent | Absent | Absent | 1-25% | Absent | Absent | Absent | Absent | 26-50% | 1-25% | Absent | 51-75% | 1-25% | 1-25% |
| Shrubs | labrador-tea | 26-50% | 1-25% | 1-25% | 51-75% | 26-50% | 76-100% | 51-75% | 51-75% | 1-25% | 1-25% | 1-25% | Absent | 1-25% | 76-100% | 51-75% | Absent | 76-100% | 76-100% | 76-100% |
| Shrubs | honeysuckles | 1-25% | 1-25% | 1-25% | Absent | 1-25% | 1-25% | 26-50% | 1-25% | 51-75% | 51-75% | 51-75% | 76-100% | 51-75% | 1-25% | 51-75% | 51-75% | 1-25% | 26-50% | 76-100% |
| Shrubs | fly honeysuckle | 1-25% | Absent | Absent | Absent | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 26-50% | 1-25% | 1-25% | 26-50% | 26-50% |
| Shrubs | pin cherry | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | Absent | Absent | 1-25% | 1-25% | 1-25% | 1-25% | Absent | 1-25% | Absent | Absent | Absent | 1-25% |
| Shrubs | choke cherry | 1-25% | Absent | Absent | Absent | 1-25% | 1-25% | Absent | Absent | 1-25% | 1-25% | 1-25% | 26-50% | 26-50% | Absent | 1-25% | 1-25% | Absent | Absent | 1-25% |
| Shrubs | currents | 1-25% | 1-25% | Absent | Absent | 1-25% | 1-25% | 26-50% | 1-25% | 51-75% | 51-75% | 26-50% | 76-100% | 51-75% | 1-25% | 51-75% | 51-75% | 1-25% | 1-25% | 76-100% |
| Shrubs | wild prickly rose | 1-25% | 26-50% | 26-50% | 26-50% | 26-50% | 26-50% | 26-50% | 51-75% | 76-100% | 51-75% | 26-50% | 51-75% | 26-50% | 1-25% | 51-75% | 51-75% | 26-50% | 26-50% | 51-75% |
| Shrubs | wild raspberry | 1-25% | Absent | 1-25% | 1-25% | 1-25% | Absent | 1-25% | 1-25% | 26-50% | 1-25% | 26-50% | 26-50% | 26-50% | Absent | 26-50% | 51-75% | 1-25% | 1-25% | 26-50% |
| Shrubs | willows | 26-50% | 51-75% | 26-50% | 1-25% | 26-50% | 26-50% | 26-50% | 26-50% | 1-25% | Absent | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 26-50% | 1-25% | 1-25% | 1-25% |
| Shrubs | red elderberry | Absent | Absent | Absent | 1-25% | 1-25% | 1-25% | Absent | Absent | 1-25% | 1-25% | 1-25% | 1-25% | Absent | Absent | 1-25% | 1-25% | Absent | Absent | Absent |
| Shrubs | low sweet blueberry | 76-100% | 76-100% | 76-100% | 76-100% | 76-100% | 76-100% | 76-100% | 76-100% | 1-25% | 51-75% | 51-75% | 1-25% | 1-25% | 76-100% | 51-75% | 26-50% | 76-100% | 51-75% | 26-50% |
| Shrubs | velvetleaf blueberry | 51-75% | 76-100% | 51-75% | 76-100% | 76-100% | 76-100% | 51-75% | 76-100% | 51-75% | 51-75% | 51-75% | 1-25% | 1-25% | 76-100% | 51-75% | 26-50% | 76-100% | 51-75% | 51-75% |
| Shrubs | viburnum | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | Absent | 1-25% | Absent | 26-50% | 26-50% | 1-25% | 51-75% | 1-25% | Absent | 1-25% | 26-50% | Absent | 1-25% | 26-50% |
| Other | large-leaved aster | 1-25% | 1-25% | 1-25% | 51-75% | 26-50% | 1-25% | 26-50% | 26-50% | 76-100% | 76-100% | 51-75% | 51-75% | 76-100% | Absent | 26-50% | 51-75% | Absent | 1-25% | 1-25% |
| Other | blue-joint grass | 1-25% | Absent | 1-25% | Absent | 1-25% | Absent | 1-25% | 1-25% | 26-50% | 1-25% | 1-25% | 26-50% | 26-50% | 1-25% | 26-50% | 51-75% | 1-25% | 26-50% | 51-75% |
| Other | sedges | 1-25% | Absent | 1-25% | 1-25% | 1-25% | 1-25% | 26-50% | 1-25% | 26-50% | 26-50% | 26-50% | 26-50% | 51-75% | 26-50% | 76-100% | 51-75% | 76-100% | 76-100% | 76-100% |
| Other | field bindweed | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent | Absent |
| Other | fireweed | 1-25% | 1-25% | 26-50% | 1-25% | 1-25% | 1-25% | 26-50% | 1-25% | 26-50% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% | 1-25% |
| Other | bracken fern | 26-50% | 1-25% | 1-25% | 26-50% | 26-50% | 1-25% | Absent | Absent | Absent | 26-50% | 26-50% | 1-25% | 1-25% | Absent | 1-25% | 1-25% | Absent | Absent | Absent |

Absent   1 - 25%   26 - 50%   51 - 75%   76 - 100%

Table 4. Asexual reproduction methods of selected species.

| | Common Name | Root Origin | | Species Origin | | |
|---|---|---|---|---|---|---|
| | | Root Suckers | Rhizomes | Root Collar Sprouts | Lower Stem Sprouts | Layering (stolons) |
| Trees | balsam fir | nil | nil | nil | nil | secondary |
| | red maple | nil | nil | primary | secondary | secondary |
| | sugar maple | secondary | nil | primary | secondary | nil |
| | yellow birch | nil | nil | primary | secondary | nil |
| | white birch | nil | nil | primary | secondary | nil |
| | black ash | secondary | — | primary | — | — |
| | larch | nil | nil | — | — | primary (north) |
| | white spruce | nil | nil | nil | nil | nil |
| | black spruce | nil | nil | nil | nil | primary |
| | red spruce | nil | nil | — | — | — |
| | jack pine | nil | nil | nil | nil | nil |
| | red pine | nil | nil | nil | nil | nil |
| | white pine | nil | nil | nil | nil | nil |
| | balsam poplar | primary | nil | secondary | secondary | nil |
| | largetooth aspen | primary | — | secondary | secondary | — |
| | trembling aspen | primary | nil | secondary | secondary | nil |
| | red oak | nil | nil | primary | — | nil |
| | mountain ash | nil | nil | secondary | unknown | nil |
| | eastern white cedar | nil | nil | nil | nil | primary (swamps) |
| | eastern hemlock | nil | nil | nil | nil | — |
| | American elm | nil | nil | primary | — | nil |

Table 4 (con't). Asexual reproduction methods of selected species.

| | Common Name | Root Origin | | Species Origin | | |
|---|---|---|---|---|---|---|
| | | Root Suckers | Rhizomes | Root Collar | Lower Stem Sprouts | Layering (stolons) |
| Shrubs | mountain maple | nil | nil | primary | secondary | secondary |
| | speckled alder | secondary | nil | primary | secondary | secondary |
| | green alder | unknown | nil | primary | secondary | nil |
| | serviceberry | secondary | nil | primary | secondary | secondary |
| | bog rosemary | nil | primary | unknown | unknown | unknown |
| | bearberry | nil | primary | nil | nil | secondary |
| | swamp birch | secondary | nil | unknown | secondary | unknown |
| | leatherleaf | unknown | unknown | unknown | unknown | secondary |
| | sweetfern | nil | primary | secondary | secondary | nil |
| | red osier dogwood | secondary | nil | secondary | secondary | primary |
| | beaked hazel | primary | nil | secondary | secondary | secondary |
| | bush honeysuckle | nil | primary | unknown | secondary | nil |
| | sheep laurel | nil | primary | unknown | secondary | secondary |
| | bog laurel | nil | primary | unknown | secondary | secondary |
| | Labrador-tea | nil | nil | unknown | secondary | primary |
| | honeysuckles | nil | secondary | secondary | primary | nil |
| | fly honeysuckle | nil | secondary | unknown | primary | unknown |
| | pin cherry | primary | nil | secondary | secondary | nil |
| | choke cherry | primary | nil | secondary | secondary | nil |
| | currants | nil | secondary | nil | secondary | primary |
| | wild prickly rose | nil | primary | secondary | secondary | secondary |

Table 4 (con't). Asexual reproduction methods of selected species.

| | Common Name | Root Origin | | Species Origin | | |
|---|---|---|---|---|---|---|
| | | Root Suckers | Rhizomes | Root Collar Sprouts | Lower Stem Sprouts | Layering (stolons) |
| Shrubs | wild raspberry | nil | primary | primary | primary | unknown |
| | willows | secondary | nil | primary | secondary | secondary |
| | red elderberry | secondary | nil | secondary | primary | secondary |
| | low sweet blueberry | nil | primary | secondary | secondary | nil |
| | velvetleaf blueberry | nil | primary | secondary | secondary | nil |
| | viburnum | nil | secondary | primary | unknown | secondary |
| Other | large-leaved aster | nil | primary | nil | nil | nil |
| | blue-joint grass | nil | primary | nil | nil | nil |
| | sedges | nil | primary | nil | nil | nil |
| | field bindweed | nil | primary | nil | nil | nil |
| | fireweed | nil | secondary | nil | nil | nil |
| | grasses* | nil | primary | nil | nil | nil |
| | bracken fern | nil | primary | nil | yes | nil |

* The Poaceae family (grasses) uses corms as a secondary method of asexual reproduction

Table 5. Sexual reproduction methods of selected species.

| | Common Name | Reproduction Class | Propagule Fruit Type | Minimum Seed Bearing Age (yr) | Periodicity of Large Seed Crops (yr) | Seeding Regeneration Strategy [1] |
|---|---|---|---|---|---|---|
| Trees | balsam fir | Monoecious | cone | 10 – 15 | 2 – 4 | SB |
| | red maple | Monoecious | samara | 4 | annually | SB |
| | sugar maple | Monoecious | samara | 40 – 60 | annually | SB |
| | yellow birch | Monoecious | catkin | 40 | annually | SSB |
| | white birch | Monoecious | catkin | 15 | 2 | CSC |
| | black ash | Dioecious | samara | — | 3 – 4 | SSB |
| | larch | Monoecious | cone | 4 – 15 | 3 – 6 | CSC |
| | white spruce | Monoecious | cone | 10 | 2 – 6 | SC |
| | black spruce | Monoecious | cone | 10 – 15 | 1 – 4 | SC |
| | red spruce | Monoecious | cone | 15 – 20 | 3 – 8 | CSC |
| | jack pine | Monoecious | cone | 3 – 15 | 3 – 4 | SC |
| | red pine | Monoecious | cone | 2 – 25 | 3 – 7 | CSC |
| | white pine | Monoecious | cone | 2 – 25 | 3 – 5 | CSC |
| | balsam poplar | Dioecious | catkin | 8 – 10 | annually | CSC |
| | largetooth aspen | Dioecious | catkin | 10 | 2 – 3 | CSC |
| | trembling aspen | Dioecious | catkin | 10 – 20 | 4 – 5 | CSC |
| | red oak | Monoecious | nut | 25 | 2 – 5 | CSC |
| | mountain ash | Perfect | pome | 15 | annually | CSC |
| | eastern white cedar | Monoecious | cone | 6 | 2 – 5 | CSC |
| | eastern hemlock | Monoecious | cone | 20 | 2 – 3 | CSC |
| | American elm | Perfect | samara | 15 | annually | CSC |

1 SB = seedling bank; SSB = soil seed bank; CSC = current seed crop; SC = serotinous cones.

Table 5 (con't). Sexual reproduction methods of selected species.

| | Common Name | Reproduction Class | Propagule Fruit Type | Minimum Seed Bearing Age (yr) | Periodicity of Large Seed Crops (yr) | Seeding Regeneration Strategy [1] |
|---|---|---|---|---|---|---|
| Shrubs | mountain maple | Monoecious | samara | — | — | CSC |
| | speckled alder | Monoecious | catkin | 7 | annually | CSC |
| | green alder | Monoecious | catkin | 5 | annually | CSC |
| | serviceberry | Perfect | pome | — | annually | SSB |
| | bog rosemary | Perfect | capsule | — | annually | — |
| | bearberry | Perfect | drupe | — | annually | — |
| | swamp birch | Monoecious | catkin | — | annually | CSC |
| | leatherleaf | Monoecious | capsule | — | annually | — |
| | sweetfern | Monoecious | nut | — | — | SSB |
| | red osier dogwood | Monoecious | drupe | 4 | 1 – 2 | SSB |
| | beaked hazel | Monoecious | nut | 2 | 5 | CSC |
| | bush honeysuckle | Perfect | capsule | — | — | — |
| | sheep laurel | Perfect | capsule | — | annually | — |
| | bog laurel | Perfect | capsule | — | annually | — |
| | Labrador-tea | Perfect | capsule | — | — | — |
| | honeysuckles | Perfect | berry | 3 | — | — |
| | fly honeysuckle | Perfect | berry | — | — | — |
| | pin cherry | Perfect | drupe | 4 | 2 – 3 | SSB |
| | choke cherry | Perfect | drupe | 2 | 1 – 2 | CSC |
| | currants | Perfect | berry | 3 – 5 | 2 – 3 | SSB |
| | wild prickly rose | Perfect | hip | 2 | 1 – 2 | SSB |

1 SB = seedling bank; SSB = soil seed bank; CSC = current seed crop; SC = serotinous cones.

Table 5 (con't). Sexual reproduction methods of selected species.

| | Common Name | Reproduction Class | Propagule Fruit Type | Minimum Seed Bearing Age (yr) | Periodicity of Large Seed Crops (yr) | Seeding Regeneration Strategy [1] |
|---|---|---|---|---|---|---|
| Shrubs | wild raspberry | Perfect | drupe | 2 | annually | SSB |
| | willow | Dioecious | catkin | 2 – 4 | — | CSC |
| | red elderberry | Perfect | drupe | — | annually | SSB |
| | low sweet blueberry | Perfect | berry | 4 | — | — |
| | velvetleaf blueberry | Perfect | berry | — | — | — |
| | viburnum | Perfect | drupe | 3 – 5 | annually | SSB |
| Other | large-leaved aster | Perfect | berry | — | annually | CSC |
| | blue-joint grass | Perfect | caryopsis | — | annually | CSC |
| | sedges | Perfect/Imperfect | achene | 1 | — | SSB |
| | field bindweed | Perfect | capsule | — | annually | SSB |
| | fireweed | Perfect | capsule | 1 | annually | CSC |
| | grasses | * | caryopsis | 1 | annually | SSB |
| | bracken fern | — | sporangium | 2 | — | — |

1 SB = seedling bank; SSB = soil seed bank; CSC = current seed crop; SC = serotinous cones.

* - can be perfect, monoecious or dioecious.

Table 6. Seed dispersal characteristics of selected species.

| | Common Name | Seed Type | Averaged Cleaned Seeds/kg | Time of Seed Ripening | Dispersed Distance (max.) | Primary Mode of Dispersal | Time of Seed Dispersal |
|---|---|---|---|---|---|---|---|
| Trees | balsam fir | winged seed | 131,120 | Aug. – Sept. | 160 m | wind, mammals | September |
| | red maple | samara | 50,352 | June – July | 660 m | wind | June – July |
| | sugar maple | samara | 13,420 | June – Sept. | 100 m | wind | June – Sept. |
| | yellow birch | samara | 983,000 | Aug. – Oct. | 100 – 200 m | wind | Aug. – Oct. |
| | white birch | samara | 3,036,000 | July – Sept. | 100 – 200+ m | wind | July – Sept. |
| | black ash | samara | 13,500 – 20,900 | June – Sept. | — | wind | July – Oct. |
| | larch | winged seed | 550,000 – 710,000 | Aug. – Sept. | 60 – 70 m | wind | Sept. – Oct. |
| | white spruce | winged seed | 497,200 | Aug. – Sept. | 40 – 60 m | wind, mammals | Sept. – Jan. |
| | black spruce | winged seed | 1,258,400 | Aug. – Sept. | 200 m | wind, mammals | Sept. – Apr. |
| | red spruce | winged seed | 222,000 - 637,000 | September | 100 m | wind | October |
| | jack pine | winged seed | 288,200 | September | 40 – 60 m | wind, mammals | all year |
| | red pine | winged seed | 114,400 | Aug. – Oct. | 20 – 40 m | wind | Oct. – Nov. |
| | white pine | winged seed | 56,320 | Aug. – Sept. | 100 – 300 m | wind, mammals | September |
| | balsam poplar | seed | — | June – July | several km | wind, water | late June – July |
| | largetooth aspen | seed | 5,600,000 | June | several km | wind | June |
| | trembling aspen | seed | 5,600,000 | June | several km | wind | June |
| | red oak | nut | 275 | Aug. – Sept. | — | gravity, mammals | Sept. – Oct. |
| | mountain ash | seed | 352,423 | Aug. – Sept. | — | birds, mammals | Aug. – Mar. |
| | eastern white cedar | winged seed | 763,000 | August | 45 – 60 m | wind, mammals | September |
| | eastern hemlock | winged seed | 580,000 | Sept. – Oct. | 30 – 40 m | wind | Oct – Nov. |
| | American elm | samara | 156,000 | May | 90 – 400 m | wind, water | June |

Table 6. Seed dispersal characteristics of selected species.

| | Common Name | Seed Type | Averaged Cleaned Seeds/kg | Time of Seed Ripening | Dispersed Distance (max.) | Primary Mode of Dispersal | Time of Seed Dispersal |
|---|---|---|---|---|---|---|---|
| Trees | mountain maple | samara | 50,866 | Sept. – Oct. | — | wind, water | Oct. – Dec. |
| | speckled alder | nut | 660,000 | August | 30 m | wind, water | October |
| | green alder | nut | 2,816,000 | Aug. – Oct. | — | wind | Aug. – Oct. |
| | serviceberry | seed | 180,800 | late June – Aug. | — | birds, mammals | August |
| | bog rosemary | seed | — | July – Aug. | — | wind | July – Aug. |
| | bearberry | nutlet | — | Aug. – Sept. | — | wind | — |
| | swamp birch | samara | — | Aug. – Sept. | — | wind | Aug. – Sept. |
| | leatherleaf | seed | — | July – Aug. | — | wind | August |
| | sweetfern | nut | 68,841 – 120,912 | July – Aug. | — | wind | August |
| | red osier dogwood | stone | 40,700 | July – Oct. | — | birds, mammals | Oct. – winter |
| | beaked hazel | nut | 1,208 | Aug. – Sept. | — | birds, mammals | — |
| | bush honeysuckle | seed | — | July – Sept. | — | birds, mammals | — |
| | sheep laurel | seed | — | late July – Aug. | — | wind | before Oct. |
| | bog laurel | seed | — | July – Aug. | — | wind | July – Aug. |
| | Labrador-tea | seed | — | July – Aug. | — | wind | — |
| | honeysuckles | seed | 312,775 – 719,163 | late June – Oct. | — | birds, mammals | — |
| | fly honeysuckle | seed | — | June – Sept. | — | birds, mammals | June – Sept. |
| | pin cherry | stone | 31,240 | late July - Aug. | — | birds, mammals | — |
| | choke cherry | stone | 10,538 | Aug. – Sept. | — | birds, mammals | Aug. – Sept. |
| | currants | seed | — | August | — | birds, mammals | Aug. – Oct. |
| | wild prickly rose | achene | — | late summer – early fall | — | birds, mammals | late spring |

Table 6 (con't). Seed dispersal characteristics of selected species.

| | Common Name | Seed Type | Averaged Cleaned Seeds/kg | Time of Seed Ripening | Dispersed Distance (max.) | Primary Mode of Dispersal | Time of Seed Dispersal |
|---|---|---|---|---|---|---|---|
| Shrubs | wild raspberry | seed | 721,600 | July – Oct. | — | birds, mammals | July – Oct. |
| | willows | seed | 4,989,600 | June – July | several km | wind, water | June – July |
| | red elderberry | stone | 629,956 | July – Aug. | — | birds, mammals | June – Nov. |
| | low sweet blueberry | seed | 4,338,783 | July – Aug. | — | birds, mammals | August |
| | velvetleaf blueberry | seed | — | July – Aug. | — | birds, mammals | August |
| | viburnum | stone | 30,464 | July – Sept. | — | birds, mammals | Spring |
| Other | large-leaved aster | seed | — | September | — | wind | — |
| | blue-joint grass | grain | 7,346,687 | Aug. – Sept. | — | wind | Aug. – Sept. |
| | sedges | achene | — | July – Sept. | — | wind | Aug. – Sept. |
| | field bindweed | achene | — | | — | wind | — |
| | fireweed | plumed seed | — | Aug. – Sept. | 10 - 300 km | wind | Aug. – Sept. |
| | grasses | grain | — | July – Sept. | — | wind | Aug. – Sept. |
| | bracken fern | spore | — | — | — | wind, water | — |

Table 7. Seed germination characteristics of selected tree species.

| Species | Viable Seeds per Kg | Dormancy[1] | Cold Stratification Period[2] (days) | Percent Germination[3] | Germination Temperature ($^{0}$ C)[4] | | | Preferred Seedbed[5] |
|---|---|---|---|---|---|---|---|---|
| | | | | | Low | Optimal | High | |
| balsam fir | 32,800 | C | 21 – 90 | 25 | 7 – 12 | 15 – 27 | 30 | MS, DW, BD, PM |
| red maple | 30,000 | None, C | 30 – 90 | 50 – 85 | — | 1 – 10 | — | MS, BD |
| sugar maple | 8,500 | C | 35 – 90 | 50 – 60 | — | 1 – 5 | 7 | MS |
| yellow birch | 467,000 | C | 21 – 30 | 20 – 40 | 7 – 12 | 18 – 29 | — | MS, BD, HM, DW |
| white birch | 1,057,000 | None, C | 60 | 15 – 60 | 3 | 18 – 30 | — | MS, HM, DW |
| black ash[6] | 3,500 | C, P, IE | 90 | 20 – 75 | — | — | — | MS |
| larch | 351,000 | None, C | 21 – 60 | 40 – 50 | 12 | 18 – 21 | 24 | MS, O, SM, BO |
| white spruce | 391,000 | C | 21 – 30 | 55 – 70 | 5 | 14 – 24 | 35 | MS, HM, DW, BD, PM |
| black spruce | 888,000 | None, C | 14 – 21 | 60 – 90 | 7 | 12 – 28 | 34 | MS, SM, PM, BO, BD |
| red spruce | 287,000 | None, C | 21 – 30 | 60 | — | 20 – 30 | 33 | MS, BD, DW |
| jack pine | 273,000 | None, C | 14 | 70 – 85 | — | 16 – 27 | — | MS, BD |
| red pine | 102,000 | None, C | 14 – 21 | 75 – 85 | 7 | 15 – 34 | — | MS, BD, PM |
| white pine | 46,000 | C | 30 – 60 | 60 – 90 | 12 | 18 – 24 | 30 | MS, PM, BD |
| balsam poplar[7] | — | None | 0 | > 90 | 5 | 10 – 40 | 45 | MS |
| largetooth aspen[7] | 4,200,000 | None | 0 | > 80 | 5 | 10 – 29 | 35 | MS |
| trembling aspen[7] | 4,200,000 | None | 0 | > 75 | — | 2 – 30 | 35 | MS, H |
| red oak | 170 | C | 30 – 60 | 40 – 70 | — | 1 – 5 | 23 | MS, H, MH |
| mountain ash[8] | 65,000 | C | 90 – 120 | 15 – 20 | — | 20 – 30 | — | — |
| eastern white cedar | 520,000 | None, C | 21 – 30 | 35 – 60 | 14 – 18 | 24 – 28 | 34 | DW, MS, H, SM, BO |
| eastern hemlock | 188,000 | C | 90 – 120 | 10 – 65 | 7 | 10 – 18 | 22 | MS, BD, DW |
| American elm | 47,000 | None | none | 10 – 60 | — | 10 – 30 | — | MS, DW, H |

Notes from Table 7

1 Dormancy refers to a state that prevents germination under environmental conditions unfavorable for growth. Dormancy may be due to the presence of biochemical inhibition (C), physical properties of the seedcoat (P) or an immature embryo (IE). Only more northern provenances of some species may possess dormancy (e.g. red maple).

2 Seedlots within a species may vary in degree of biochemical dormancy such that stratification may not be necessary for high percent germination. For those species sometimes lacking dormancy, a stratification period is identified, and may be higher during years of heavy seed crops.

3 Percent germination expected from natural seedfall (filled and unfilled seed) that has been stratified (where necessary) and exposed to optimal temperature for germination.

4 Temperatures below which percent germination of non-dormant, fully imbibed seed is markedly reduced (LOW), optimal for germination, or above which percent germination is significantly reduced (HIGH).

5 Seedbed preference in approximate order of decreasing receptivity. Seedbeds include mineral soil (MS), humus (H), humus/soil mixture (HM), pioneer mosses (PM), sphagnum mosses (SM), decaying wood (DW), burned duff (BD), burned organic soils (BO) and organic (O). Litter or forest duff are generally poor seedbeds and are not listed. Receptivity of all seedbeds increases when precipitation and humidity are high enough to maintain seedbed moisture conditions adequate to support germination and establishment. Therefore, thin, moist litter layers may be receptive. Decayed wood is receptive only when occurring in the shelter of uncut stands where moisture content remains high. Certain seedbeds occur only on specific ecosites (e.g. sphagnum moss) and preference ranking should be restricted to these ecosites.

6 Black ash requires a 60 day warm incubation period (20 to 25 C) to allow embryo to mature prior to stratification.

7 Seed viability (i.e. percent germination) of *Populus* spp. declines rapidly within a few weeks of dispersal.

8 Information supplied refers to *Sorbus americana*.

NOTE: Germination of dormant seeds may be improved in the presence of light. It is not an absolute prerequisite for germination of non-dormant seed of any of the species listed. Seed moisture contents of 35 to 45 percent of oven dry weight are optimal for germination of species listed. This target moisture content can be achieved by soaking seeds in aerated water for 24 to 48 hours.

Table 8. Environmental requirements and adaption to environmental stress.

| Species | Environmental Requirements | | | Tolerance or Adaption to Environmental Stress[2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water | Nutrients | Shade | Soil pH[1] | Drought | Water-logging[3] | Frost[4] | High Temp | Wind[5] |
| balsam fir | M | M | Very Tolerant | 5.0 – 7.0 | L | M | L – M | — | L |
| red maple | L – M | L – M | Tolerant | — | M | M – H | L | — | M |
| sugar maple | M | M | Very Tolerant | 5.5 – 7.3 | L | L | L – M | — | M |
| yellow birch | M | M – H | Intermediate | Acid Intolerant | L | L | L – M | — | M |
| white birch | M | M | Very Intolerant | 5.0 – 7.0 | M | L | L | L | M |
| black ash | — | M | Intolerant | 4.4 – 8.2 | — | M – H | M – H | — | L |
| larch | L – M | L – M | Very Intolerant | 5.5 – 7.6 | L – M | M | M | — | L – M |
| white spruce | M | M | Intermediate to Tolerant | 4.7– 6.5 | L – M | L – M | L – M | — | L – M |
| black spruce | L – M | L | Intermediate to Tolerant | 5.0 – 7.0 | L – M | M | M | — | L – M |
| red spruce | M | M | Tolerant | 4.0 – 5.5 | L | M | L | — | L – M |
| jack pine | L | L | Very Intolerant | 4.5 – 7.0 | H | L | M | — | M – H |
| red pine | L | L – M | Intolerant | 5.2 – 6.5 | M – H | L | M | — | H |
| white pine | M | M | Intermediate | 4.7 – 7.3 | M | L – M | M – H | — | M – H |
| balsam poplar | M – H | M – H | Very Intolerant | Acid Intolerant | L | M | L | — | — |
| largetooth aspen | M – H | M – H | Very Intolerant | 4.8 – 6.5 | M | L – M | M | — | M – H |
| trembling aspen | M – H | M – H | Very Intolerant | 5.3 – 6.5 | L – M | L – M | L | L | M |
| red oak | L – M | M | Intermediate | — | M – H | L – M | M – H | — | H |
| mountain ash | L – M | M | Intolerant | 4.5 – 5.5 | M | L | L | — | — |
| eastern white cedar | M | L – M | Tolerant | 5.5 – 7.2 | M | M – H | M – H | — | L – M |
| eastern hemlock | M | M | Very Tolerant | 5.0 – 7.0 | L | — | M | L | L – M |
| American elm | L – M | M | Intermediate | 5.5 – 8.0 | M | M – H | L – M | — | M |

Notes from Table 8

1 Range in soil pH in which optimal growth occurs. Some species occasionally inhabit extremely acid or alkaline soil microsites outside the range given.

2 Tolerance and adaptations are ranked relative to that expected for young seedlings, with exception of wind, which refers to wind firmness of mature trees.

3 Waterlogging refers to transient increases in water table or flooding events where soil moisture content increases dramatically and soil aeration is reduced to injurious levels. Species that inhabit wet soils are not necessarily tolerant of waterlogging.

4 Frost tolerance rankings are based on species differences in time of spring shoot flushing and predisposition to damage by a late spring (June) frost.

5 Tolerance of mechanical damage by wind refers to risk of uprooting or windthrow as opposed to stem breakage. The risk of windthrow is largely a function of rooting habit and rooting depth. Rooting depth of all species is affected by soil depth or depth of water table, with rooting depth decreasing and risk of windthrow increasing with higher water tables. Species were ranked based on their typical rooting patterns exhibited on commonly inhabited ecosites. For species that inhabit both wet and relatively dry sites (e.g. *Thuja occidentalis*), windthrow tolerance is lower on wetter sites.

• Environmental requirements or levels of stress tolerance are ranked as low (L), moderate (M) and high (H). Light requirements are expressed in terms of classical shade tolerance classification.

# Response to Disturbance

The response of plant species to disturbance is dependent upon their life history characteristics, regeneration strategy and physiological traits (Grime 1977). Plant species have adapted (i.e. evolved through natural selection) to specific combinations of habitat disturbances and resource availability. It is through these adaptations that plants respond to silvicultural disturbances.

Disturbance refers to events at various spatial scales that limit plant biomass accumulation through its partial or total destruction (Grime 1977). Disturbances may be natural (e.g. wildfire, flood, wind) or of human origin (e.g. logging, prescribed burning). Vegetation response to disturbances depends on a plant species regeneration strategy, the severity of the disturbance and micro-environmental conditions created by the disturbance. The impact of forest management activities on vegetation response is discussed below.

## Overstorey Removal

Species composition of post-logging vegetation is dependent upon the amount of overstorey removed and the harvesting method used. The presence of a residual canopy provides a seed source for natural regeneration and moderates seedbed micro-environments, promoting germination (**Tables 6** and **7**). Reduction in canopy density increases the solar radiation received by a site and alters energy exchange between the atmosphere and the ground. The resultant increase in light availability, diurnal range of air and soil temperature, and reduction in humidity are greater, the larger the reduction in overstorey. The physiological response of species to changes in micro-environment, resource availability and risk of environmental stress of the site affect the physiology and determine the composition and growth of post-logging vegetation (seed origin and vegetative reproduction) (**Table 8**). Canopy manipulation to create favorable understorey conditions for target crop species and/or inhibition of non-crop species is fundamental to partial cutting systems used in managing mid-tolerant and tolerant species.

Harvesting method influences post-logging vegetation through the degree of disturbance to the forest floor and the regeneration strategy (**Table 9**). Disturbance of the organic layers of the soil can stimulate site colonization by seed banking species. Removal of the organic layer and exposure of mineral soil provides sites for invasion by airborne seed and promotes natural regeneration. Vegetative reproduction through sprouting or root suckering may also be stimulated or inhibited, depending on the degree of disturbance to stems, roots and rhizomes. Careful logging techniques can be used to conserve advance reproduction (e.g. layering of black spruce) when these plants are to be used as a source of natural regeneration.

In general, those sites where the forest floor remains virtually undisturbed following logging support vegetation that most resembles the understorey species composition that existed before logging (Dyrness 1973) (**Table 9**). On these sites, residual species often expand via the sprouting of basal buds, rhizomes, and root suckers following overstorey removal and virtually exclude invading species (Yang and Fry 1981). Typically, winter harvesting disturbs the ground surface less than summer harvesting (Campbell 1981). This may result in less germination of seed from species such as pin cherry, raspberry or Canada blue-joint grass.

## Prescribed Fire

A plant's response to fire depends on several factors including fire severity (**Table 9**), phenology (McLean 1969, Noste *et al*. 1987, Haeussler 1991), and post-fire micro-site conditions. Fires can be categorized as light, moderate or severe (Haeussler 1991). Species composition re-established after light surface fires will closely resemble that of the pre-burn condition, especially where the majority of species regenerate from underground plant parts (Smith and Sparling 1966, Smith and James 1978). In contrast, severe fires consume the LFH and increase mineral soil surface temperatures to lethal levels that can reduce, and in some cases eliminate, the ability of plants to reproduce vegetatively. In these instances, regeneration must be from seed on the site or from adjacent unburned forests. Plant species can be ranked according to relative fire resistance of the root system. "Susceptible" species are those having fibrous root systems or producing stolons or rhizomes growing above mineral soil. "Moderately resistant" species usually have fibrous roots with rhizomes growing less than 5 cm below the mineral soil surface. "Resistant" species are those with rhizomes growing between 5 and 13 cm below the mineral surface and species capable of regeneration via adventitious buds formed on their tap root (McLean 1969).

Seasonal changes in soil moisture and carbohydrate reserves of underground plant parts affect the quantity and vigor of regrowth (Noste *et al.* 1987). Soil moisture affects the transfer of heat to underground plant parts and therefore damage to root systems and soil seed banks (Noste *et al*. 1987). Temperatures hot enough to destroy roots, rhizomes or seeds rarely occur more than a few centimetres below the surface of wet duff (Haeussler 1991).

Post-fire increases in soil moisture, soil temperature, understorey light and the removal of surface litter and senescent plant parts stimulate both vegetative and seedling growth (Smith and James 1978).

## Mechanical Site Preparation

The response of plant species to mechanical disturbance depends on the extent and type of disturbance. The degree of disturbance, based upon the removal of subsurface vegetation, can be described as localized or extensive (Delong 1989, Sutherland and Foreman 1995). Localized disturbances are those where small areas of mineral soil are exposed and most vegetation is left relatively undisturbed (e.g. spot scarifying, inverting, mounding on upland soils, disc trenching or drag units of barrels and/or tractor pads and/or anchor chains). In contrast, extensive disturbances include those where large areas of mineral soil are exposed (e.g. angle- or V-blade windrowing or corridoring), reducing vegetation composition and structure.

Five types of disturbance (**Table 9**), differentiated by relative treatment effects on organic and mineral soil layers, have been described (Sutherland and Foreman 1995):

- **Overstorey removed, ground undisturbed:** little change to the floristic composition, but total biomass is reduced.
- **L and part of F or Of horizon removed:** stimulates vegetative growth from the lower stem, roots and rhizomes, and can provide favorable germination sites for both wind-borne seed and seed in the soil seed bank.
- **LFH displaced and mineral soil depressed, level or raised:** composition and structure of vegetation outside of the mineral soil patch is unchanged, and there will be no vegetation on the mineral soil until plants seed in or sprout up. Vegetation developed on the mineral soil is often of a different composition than vegetation on the undisturbed areas. Areas of mineral soil are soon occupied by pioneer species, usually by seeding-in.
- **LFH inverted with mineral soil cap:** germination of wind-borne seed on mounds or berms may be inhibited owing to lower soil moisture and higher soil surface temperatures. Rhizomes tend to develop along the berms.
- **LFH and mineral soil mixed:** response differs depending upon the depth and intensity of mixing. For example, deep mixing will reduce the germination potential of the soil seed bank and intense mixing will reduce the potential of root suckers.

## Cutting

The effectiveness of a cutting operation is dependent upon the species and sites being cut, the seasonal timing of the cut and the height, angle and smoothness of the cut. Cutting is most effective when the target species are not overly dense and do not sprout or sucker. As conifers do not sprout they are easily controlled by this method. Many hardwood species sprout vigorously after cutting (Bell 1991). In general, when a single hardwood stem is severed, it will give rise to multiple shoots. If the original brush was dense, growth after cutting may form a very dense canopy at a lower level and be more competitive than the original brush canopy (Campbell 1981). Stems cut during the dormant season sprout more vigorously than those cut during the growing season because of seasonal variation in carbohydrate resources in underground organs. Cutting when carbohydrate reserves are low, typically after leaf out in early summer, reduces growth of sprouts (Bell 1991). Cut height also affects vegetative growth. Species which exhibit stem or root collar-sprouting (e.g. alder and dogwood) should be cut as low as possible to the ground (Harrington 1984), while root-suckering species (e.g. aspen) should be cut higher (i.e. 50 to 75 cm, but below live crown) to reduce suckering (Stoeckeler 1947, Wagner *et al.* 1995). The angle and aspect of the cut faces of stumps have been noted to affect the sprouting of alder (Harrington 1984). Ragged surfaces created by dull cutting tools are thought to decrease the numbers and vigor of sprouts for tall shrubs and trees (Farnden 1992).

## Herbicides

Species' susceptibility to herbicides, phenology, reproductive characteristics and, in the case of soil active herbicides, habitat, will affect treatment success. Herbicide susceptibility plays a very important role in the rate of recovery from treatment. Canada blue-joint grass, for example, is resistant to 2,4-D and can reproduce rapidly through rhizomes after a 2,4-D application. Knowing the relative susceptibility of species to herbicides licensed for vegetation management enables forest managers to select the herbicide which will provide desired results. Species susceptibility tables for 2,4-D, Velpar®-L (a.i. = hexazinone), Vision® (a.i. = glyphosate), and Release® (a.i. = triclopyr) are presented in **Table 10**.

Herbicide susceptibility of both crop and non-crop species is directly related to phenology. From a review of the optimum timing of herbicide applications (Carruthers and Towill 1988) and autecology summaries (Bell 1991, Haeussler *et al*. 1990) the following broad recommendations can be made:

- Growth-promoting herbicides, such as 2,4-D and triclopyr, are most effective in late July to early August, at the end of rapid shoot elongation.
- Foliar active, photosynthesis-inhibiting herbicides, such as Vision®, are most effective in August when carbohydrates are being translocated to the root system.
- Soil active, photosynthesis-inhibiting herbicides, such as hexazinone, are most effective in May to June, prior to shoot elongation, when roots are actively growing, and the ground is neither frozen nor dried out.

Wind-borne and buried seed play a very important role in post-herbicide recovery, especially in the case of foliar active herbicides. These compounds do not possess soil-active properties and therefore, do not control post-spray germinants. Fireweed, asters, alder, birch and Canada blue-joint grass typically invade herbicide treated areas via wind-borne seed. Buried seeds, dormant in the soil seed bank for many years, germinate in response to environmental changes following herbicide applications. Red raspberry and pin cherry rely heavily upon this reproductive strategy. Generally, recruitment from either wind-borne seed or buried seed can best be controlled with soil-active herbicides.

Soil properties influence the movement of soil-active herbicides into the rooting zone. Effectiveness of root uptake is reduced on heavy textured soils (i.e. clay) and on soils with high organic content. Comparatively greater quantities of chemical are required to control vegetation on these soils than on medium textured soils.

## Application of Autecology Tables

This section provides direction on how to apply autecology **Tables 1** through **8**. Users are required to apply their knowledge of basic ecology to make interpretations of how plant communities will respond to disturbances caused by silvicultural operations. These interpretations will be site specific and dependent on the management objectives. **Table 11** presents a summary of some of the key considerations to be evaluated at each silvicultural treatment stage and cross referenced to the autecology tables.

## Summary

Species' response to disturbance is not a single ecological characteristic, but the collective strategies of a plant species to evade, escape or resist disturbance. This includes all the adaptive mechanisms plants have evolved (i.e. life history characteristics, regeneration strategies, and physiological traits) to respond to various kinds of natural disturbances such as fire, browsing, insects and disease. Plants use these same mechanisms to respond to silvicultural disturbances (e.g. overstorey removal, prescribed fire, mechanical site preparation, cutting and herbicides). With the focus on integrated forest management and development of vegetation management techniques to promote sustainable forestry, it has become critical for forest managers to use information on plant autecology to predict how crop and non-crop species will respond to natural and silvicultural disturbances. Information on the autecology and physiology of 55 plant species occurring in the Boreal Forest Region of Ontario, collected from a number of sources, are presented in eleven tables for use in forest management decision making processes.

Table 9. Relative influence of microsite categories on vegetation (adapted from: Sutherland and Foreman 1995).

Microsite description
Effect of disturbance on reproduction

↑ = promotes (↑↑ = strongly promotes)
0 = no effect
↓ = discourages (↓↓ = strongly discourages)

| Microsite Categories | | | Vegetative Reproduction | | | Sexual Reproduction | |
|---|---|---|---|---|---|---|---|
| | | | Shoot Origin Sprouting | Root Origin Sprouting | | Windborne Seeders | Seed Bankers |
| | | | | Roots in Organic Layer | Roots in Mineral Soil | | |
| | | | e.g. maple, alder, birch, dogwood, hazel, willow, Labrador-tea | e.g. grasses, blueberry | e.g. poplar, rose, raspberry | e.g. grasses, birch, fireweed, poplar, willow | e.g. dogwood, cherry, rose, raspberry, blueberry |
| | Undisturbed | | 0 | 0 | 0 | 0 | 0 |
| Harvest | Overstorey removed; ground undisturbed | | ↑↑ | ↑ | ↑ | 0 to ↑[1] | ↑ |
| Mechanical Site Preparation | Organic partially displaced | L and part of F | ↑ | ↑ | ↑ | ↑ | ↑↑ |
| | | Part of Of layer | ↓[2] | ↓ to ↑[2] | not applicable | ↑ | ↑ |
| | LFH removed and mineral soil either: | depressed | ↓↓ | ↓↓ | ↓↓ to ↓[3] | ↑↑ | ↓↓ |
| | | level | ↓↓ to ↓[4] | ↓ | ↑↑ | ↑↑ | ↓ |
| | | raised | ↓↓ | ↓↓ | ↓↓ to ↓[5] | ↑ | ↓↓ |
| | LFH inverted with mineral soil cap | | ↑ to ↑↑ | ↓ to ↑[5] | ↓ | ↑ | ↓ |
| | LFH and mineral soil mixed | | ↑ to ↑ | ↓ to ↑ | ↓ to ↑ | ↑↑ | ↑↑ |
| Prescribed Fire | Light[6] | | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑↑ |
| | Moderate[7] | | ↓ | ↑ | ↑↑ | ↑↑ | ↑ |
| | Severe[8] | | ↓↓ | ↓↓ | ↓ | ↑↑ | ↓↓ |
| Cutting | Active | < 25 cm | ↑ | ↑ | ↑ | — | — |
| | | > 25 cm | ↑ | ↑ | ↑ | — | — |
| | Dormant | < 25 cm | ↑↑ | ↑↑ | ↑↑ | — | — |
| | | > 25 cm | ↑↑ | ↑ | ↑ | — | — |

Notes from Table 9

1 Will promote if organic layer is shallow and/or moist.

2 Will promote *Ledum* and *Vaccinium* species.

3 Control of sprouting depends on removal of root systems.

4 Control of sprouting is improved for species that tend to root in the organic layer.

5 Control of sprouting increases with increased depth of scalping.

6 Moss/litter layer is singed. More than 60 percent of the shrub canopy has been consumed. Some leaves and small twigs remain on plants and are either unharmed or slightly singed.

7 Most of the moss/litter layer is charred but not ashed. 40 to 80 percent of the shrub canopy has been consumed. Only medium-sized twigs (0.5 to 1.5 cm diameter) remain and are charred.

8 Moss/litter and duff layers have been consumed and only ashes remain on the soil surface. More than 95 percent of the shrub canopy has been consumed, with only large stems (more than 1.5 cm diameter) remaining or charred remains of the main stem.

Table 10. Susceptibility of selected competitor and crop species to selected herbicides for forestry use in Ontario.

| | Species | 2,4-D | Velpar® - L | Vision® | Release® |
|---|---|---|---|---|---|
| Trees | balsam fir | R | R | R | R |
| | red maple | I – R | S – I | S | S – I |
| | sugar maple | I – R | — | S | — |
| | yellow birch | S | — | — | — |
| | white birch | S | I | S – I | S |
| | black ash | — | — | — | — |
| | larch | — | — | — | — |
| | white spruce | R | I – R | R | R |
| | black spruce | R | I – R | R | R |
| | red spruce | — | — | — | — |
| | jack pine | R | S | I – R | I – R |
| | red pine | R | VR | R | R |
| | white pine | R | I | R | R |
| | balsam poplar | S – R | S – I | S – I | S |
| | largetooth aspen | — | — | — | — |
| | trembling aspen | S – I | S – I | S – I | S |
| | mountain ash | — | S | S | — |
| | eastern white cedar | — | — | — | — |
| | eastern hemlock | — | — | — | — |
| Shrubs | mountain maple | I – R | I | S – I | S |
| | speckled alder | S – I | R | S – I | S |
| | green alder | S – I | R | S | S |
| | serviceberry | S – R | I | S | S |
| | bog rosemary | — | — | — | — |
| | bearberry | — | — | — | — |
| | swamp birch | — | — | — | — |
| | leatherleaf | — | — | — | — |
| | sweetfern | I | I | S | — |
| | red osier dogwood | S – I | I – R | I – R | S |
| | beaked hazel | S | I – R | S – I | S – I |
| | bush honeysuckle | — | I | I | — |
| | sheep laurel | I | S | I | R |
| | bog laurel | — | — | — | — |
| | Labrador-tea | S | — | R | I – R |
| | honeysuckles | — | I | S | R |
| | fly honeysuckle | — | I | S | R |
| | pin cherry | S | I | S | S |
| | choke cherry | S – R | I | S | S |
| | currants | I | I | I | S |

Legend: VR = Very Resistant; R = Resistant; I = Intermediate; S= Susceptible;
— = no information

Table 10 (con't). Susceptibility of selected competitor and crop species to selected herbicides for forestry use in Ontario

| | Species | 2,4-D | Velpar® - L | Vision® | Release® |
|---|---|---|---|---|---|
| Shrubs | wild prickly rose | R | I | S – I | S |
| | wild raspberry | R | S | I | S |
| | willows | S | I | I – R | S |
| | red elderberry | I | I | S – I | S |
| | low sweet blueberry | S | VR | S – I | S |
| | velvetleaf blueberry | S | VR | S – I | S |
| | viburnum | R | I | S | — |
| Other | large-leaved aster | — | S | — | — |
| | blue-joint grass | R | S | I | R |
| | sedges | R | S | S – I | — |
| | field bindweed | I | — | S – I | — |
| | fireweed | S – I | I – R | I | S |
| | grasses | VR | S | S – I | R |
| | bracken fern | R | S – I | S – I | I – R |

Legend: VR = Very Resistant; R = Resistant; I = Intermediate; S = Susceptible;
— = no information

Table 11. Application of autecology tables one through eight.

| | Table 1 Form, Longevity and Growth Habit | Tables 2 & 3 Vegetation and Site Types | Table 4 Asexual Reproductive Methods | Table 5 Sexual Reproduction Methods | Table 6 Seed Dispersal Characteristics | Table 7 Seed Germination Characteristics | Table 8 Environmental Requirements, Adaptations to Stresses |
|---|---|---|---|---|---|---|---|
| Pre-Harvest | What is the maturity of the stand?<br><br>What is the biological rotation of the stand? | Occurrence of crop and non-crop species? | Is there advanced regeneration potential?<br><br>Could careful logging operations be planned? | What is the periodicity of good seed crops?<br><br>Natural seedling regeneration strategy? | Time of year for seed collection?<br><br>Cut layout pattern?<br><br>Time of harvest? | Quantity of seed needed for artificial regeneration?<br><br>Appropriate artificial regeneration techniques (e.g. nursery practices)?<br><br>Seedling production? | Matching species to site?<br><br>Predicting regeneration success? |
| Silvicultural System/Harvest Method (Also see Table 9) | N/A | Occurrence?<br><br>Application and timing of treatment? | Conserve advanced regeneration?<br><br>Promote/ inhibit suckering? | Natural seed source availability? | Which silvicultural system should be used (clear cut, seed-tree, shelterwood or selection)? | N/A | Selection of silviculture system? |
| Logging Method | N/A | Occurrence?<br><br>Application and timing of treatment? | Conserve advanced regeneration?<br><br>Careful logging?<br><br>Abundance and distribution of slash? | Distribution of cone bearing slash?<br><br>Does logging impact the potential for natural seedling regeneration? | Seed dispersal at time of harvest? | N/A | Should slash be used to protect the site from drought or high temperatures? |

Table 11. Application of autecology tables one through six. (continued)

| | Table 1 Form, Longevity and Growth Habit | Tables 2 & 3 Vegetation and Site Types | Table 4 Asexual Reproductive Methods | Table 5 Sexual Reproduction Methods | Table 6 Seed Dispersal Characteristics | Table 7 Seed Germination Characteristics | Table 8 Environmental Requirements, Adaptations to Stress |
|---|---|---|---|---|---|---|---|
| Site Preparation (Also see Table 9) | Is there potential for root disturbance? | Occurrence?<br><br>Application and timing of treatment? | Advanced regeneration?<br><br>Root suckering species?<br><br>Promotion or inhibition of vegetative reproduction? | How may site prep affect the soil seed and seedling banks? | When should site prep be done to promote crop or inhibit competitor regeneration? | Seedbed requirements? | Micro-site amelioration? |
| Regeneration | Site occupancy through suckering? | Occurrence?<br><br>Application and timing of treatment? | Is there potential for natural regeneration or competition problems? | Natural seed availability? | How much seed is needed?<br><br>Dispersal distances?<br><br>Methods and timing for natural regeneration? | How much seed is needed?<br><br>Kg of seed for seeding operations? | Micro-site selection? |
| Tending (Also see Table 10) | Could chemicals translocate through root grafts?<br><br>Canopy structure? | Occurrence?<br><br>Application and timing of treatment? | What treatments may be required to control suckering and basal sprouts? | Invasion of vegetation through seedbank and wind borne seed? | Invasion from wind borne seed? | N/A | Competition for water, light and nutrients?<br><br>Nurse crop potential? |

# Appendix 1: Glossary of Autecology Terms

| | |
|---|---|
| achene | a small dry, nonsplitting one-seeded fruit, with distinct seed attached to the ovary wall at only one point |
| adventitious | arising from unusual positions, as in buds on roots |
| asexual | referring to any type of reproduction which does not involve the union of sex-cells (gametes) |
| berry | a pulpy, nonsplitting fruit developed from a single pistil and containing one or more seeds |
| calyx | the outermost group of floral parts |
| capsule | a dry, usually many seeded fruit that splits at maturity to release its seeds |
| caryopsis | a simple, dry, one-sided, nonsplitting fruit with seed firmly attached to the entire ovary wall |
| catkin | a scaly spike bearing inconspicuous and usually unisexual flowers |
| clone | all plants reproduced asexually from a common ancestor and having identical genotypes |
| cone | the male or female reproductive organs of conifers |
| dioecious | with male and female reproductive organs borne on separate plants |
| dormancy | a state of reduced activity in seeds that prevents germination under favorable environmental conditions |
| drupe | a fleshy, usually one-seeded fruit whose seed is completely enclosed in a hard, bony endocarp |
| endocarp | the inner wall layer of a ripened ovary |
| germination | the resumption of active growth in the embryo of a seed, as demonstrated by the protrusion of a radicle (embrionic root axis) |
| grain | a small hard seed or seed-like fruit, as for any of the cereals |
| herb | a non-woody flowering plant |
| hip | the fleshy, false fruit of the rose |
| inflorescence | a floral axis with its appendages |
| 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 |

monoecious — with male and female reproductive organs in separate flowers on separate plants

nut — a dry, non-splitting, one-seeded fruit with a woody or leathery outer surface, often encased in a husk

nutlet — a small nut

perfect — having both functional male and female reproductive organs

phenology — study of the relations between seasonal climatic changes and periodic biological phenomena such as the flowering and fruiting of plants

pome — the apple-pear type of fruit, in which the true fruits are surrounded by an enlarged fleshy calyx tube and receptacle

receptacle — the end of the flower stalk on which floral parts are borne

rhizome — a horizontal stem that bears roots and leafy shoots

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

samara — a dry, non-splitting, winged fruit, one or two-seeded

seedbank — the store of dormant seeds buried in the soil

seedbed — the soil, forest floor or other media on which seed falls

serotiny — refers to cones that remain closed on the trees for one or more years and may open by exposure to temperature ≤ 50 C

spikelet — an elongated inflorescence, consisting of one or more flowers

sporanium — an organ in which spores are produced

spore — a one-celled asexual reproductive organ, almost exclusively associated with non-flowering plants (e.g. mosses, fungi)

sprout — any shoot arising from a plant

stolon — an elongated 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 C) or warm conditions

sucker — a shoot or tree originating from adventitious buds on roots

vegetative reproduction — reproduction by a root, leaf or some other primary vegetative part of a plant

# ***Section IV***

## Silvicultural Decision Tools

This chapter provides a list and short description of tools currently available for silvicultural decision-making in boreal Ontario. The emphasis is on "tools" as opposed to references or information sources. The distinction is somewhat grey. The section concentrates on information that provides quantitative or discrete outputs used directly in a planning or field application.

Today, forest management plans contain data and prescriptions spanning three levels of context:

1. **Tree level:** tools required at this level must address prescriptions or decisions centred on an individual tree. Examples are an Area of Concern prescription for a tree containing an eagle's nest or a system quantifying competition levels on a site where each crop tree is evaluated individually for its competitive status.

3. **Stand level:** tools required at the stand level are probably the most commonly used. They are many and varied in what they measure but are similar in that they aggregate results from individual trees into a composite result for a stand. Examples are growth and yield models, and FRI attributes.

3. **Forest/landscape level:** wood supply and habitat analyses for a management unit are probably the most commonly used examples of forest decision-making at this level. In the future, tools required at this level will also address issues that span administrative and management unit boundaries. For example, the spatial and temporal distribution of upland black spruce stands across northwestern Ontario as affected by forest management plans may be quantified using a landscape-level tool.

Table 1. Silvicultural tools relevant to forest management in boreal Ontario and the most appropriate scale for their use.

| Silvicultural Tools | Tree | Stand | Forest/Landscape |
|---|---|---|---|
| FEC and ecosite manuals | | X | |
| Stand establishment keys/guides | | X | |
| Competition index methodology | X | X | |
| Local volume tables | X | | |
| Site index curves, soil-site equations | X | X | |
| Stand density management tools | | X | |
| Growth and yield equations/ tables/decision systems | X | X | |
| Economic/financial analysis tools | | X | X |
| SFMM | | | X |
| LEAP | | | X |
| LDA | | | X |
| RHESSys | | | X |
| SEIM | | | X |

# TREE AND STAND LEVEL TOOLS

Summary table for tree and stand level silvicultural tools and the stage of stand development where each is best applied. Details for each follow the table.

| Tools | Stage of Stand Development | | | | |
|---|---|---|---|---|---|
| | Pre-sapling | Sapling | Immature | Mature | Overmature |
| FEC and ecosite manuals | | | | X | X |
| Pre-harvest survey | | | X | X | X |
| Photo-interpretation keys | | | | X | X |
| Site preparation guide | X | | | | |
| PC seed | X | | | | |
| Competition index | X | | | | |
| Integrated silviculture decision key | X | | | | |
| Critical silvics guides | X | | | | |
| Black spruce tending key | X | | | | |
| Cone scattering key | X | | | | |
| Slash pile burning key | X | | | | |
| Advance growth photo key | | | | X | X |
| NE advance growth key | | | | X | X |
| Density management tools | | X | X | | |
| Black spruce productivity key | | | | X | |
| Growth and yield equations/tables | | | X | X | X |

# Tools for Measuring Pre-harvest Attributes

## Site Characteristics

| | |
|---|---|
| Name: | **Northwest FEC manual** |
| Description: | A pocket-sized field guide for northwestern Ontario containing site-specific keys and fact sheets to classify pieces of forest land into vegetation types (40) and soil types (22). The manual is a field tool intended for application at the "stand level," normally within forested areas less than 10 ha. The system was developed for use in relatively mature (> 50 year-old) natural stands. Sketches of the 23 plant species used in the vegetation key, and background soil information required for the soil key are included. |
| Available from: | Lakehead University bookstore |
| Reference: | Sims, R.A., Towill, W.D., Baldwin, K.A., Uhlig, P. and Wickware, G.M. 1997 (revised). Field guide to the forest ecosystem classification for northwestern Ontario. Ont. Min. Nat. Resour., NWST, Thunder Bay, Ont. FG-03. 176 p. |

| | |
|---|---|
| Name: | **Northwest Ecosite manual** |
| Description: | A pocket-sized field guide providing a framework for classifying and mapping terrestrial and wetland ecosites in northwestern Ontario. Ecosites are mappable, ecological land uses appropriate for describing forest ecosystems at a scale compatible with the FRI. Forty forested and wetland ecosites are described. Factsheets, keys and supporting information are included. |
| Available from: | Lakehead University bookstore |
| Reference: | Racey, G.D., Harris, A.G., Jeglum, J.K., Foster, R.F. and Wickware, G.M. 1996. Terrestrial and wetland ecosites of northwestern Ontario. Ont. Min. Nat. Resour., NWST, Thunder Bay, Ont. FG-02. 94 p + appendices. |

| | |
|---|---|
| Name: | **Northeast FEC manual** |
| Description: | A pocket-sized field guide for northeastern Ontario containing site-specific keys and fact sheets to classify pieces of forest land into 16 site types. The manual is a field tool intended for application at the "stand level," normally within forested areas less than 10 ha. The system was developed for use in relatively mature (> 50 year-old) natural stands. |
| Available from: | Lakehead University bookstore |
| Reference: | McCarthy, T.G., Arnup, R.W., Niepolla, J., Merchant, B.G., Taylor, K.C. and Parton, W.J. 1994. Field guide to forest ecosystems of northeastern Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont. FG-01. 222 p. |

| | |
|---|---|
| Name: | **Humus form guide** |
| Description: | A pocket-sized field guide containing keys, photos, and background information to identify and classify forest humus forms in northwestern Ontario. The guide is intended as a field tool for use in mature natural stands. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Sims, R.A. and Baldwin, K.A. 1996. Forest humus forms in northwestern Ontario. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cen., Sault Ste. Marie, Ont. NODA/NFP Tech. Rep. TR-28, NWST, Thunder Bay, Ont. TR-100. 51 p. |

## Tree and Stand Characteristics

| | |
|---|---|
| Name: | **Aulneau FEC photo-interpretation keys** |
| Description: | A report describing a method used to approximate vegetation and soil types from aerial photos. The report contains photo-interpretation keys for soil and vegetation types on the Aulneau Peninsula, soil type keys for areas near Red Lake and Atikokan. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Wickware, G.M. and Associates. 1989. Photo interpretations of the NWO FEC vegetation and soil types for the Aulneau Peninsula: northwestern Ontario. Ont. Min. Nat.. Resour., NWOFTDU, Thunder Bay, Ont. TR-54. 23 p. |

| | |
|---|---|
| Name | **FEC/budworm model** |
| Description: | A report containing photo-interpretation keys for soil and vegetation types, with algorithms for predicted stand-level vulnerability to spruce budworm |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference | Wickware, G.M. and Sims, R.A. 1990. Evaluation of stand vulnerability to spruce budworm attack using GIS. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TR-59. 8 p. |

| | |
|---|---|
| Name: | **Pre-harvest survey** |
| Description: | A technical note describing the rationale and benefits of doing pre-harvest surveys (pre-harvest silvicultural prescriptions). A step-by-step approach for developing a comprehensive, site-specific reforestation plan is presented. |
| Available from: | Northeast Science & Technology, Timmins |
| Reference: | Bidwell, P.K., Turner, B., Archibald, D.J. and Maurer, N. 1996. An approach to pre-harvest silviculture prescriptions in boreal Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont.TN-014. 12 p. |

# Tools for Measuring Post-harvest Attributes

## Initiation (Establishment) Stage

| | |
|---|---|
| Name | **Site prep guide** |
| Description: | A report containing a photo series and fact sheets describing mechanical site preparation equipment and opportunities to create seedbed conditions for germination and growth of seedlings. Information has been subdivided into three sections: fundamental principles, practical application, and results. The framework for this work is the northwestern Ontario FEC. |
| Available from: | Canadian Forest Service, Sault Ste. Marie |
| Reference | Sutherland, B.J. and Foreman, F.F. 1995. Guide to the use of mechanical site preparation equipment in northwestern Ontario. Nat. Res. Can., Can. For. Serv. 186 p. |

| | |
|---|---|
| Name | **Competition Index** |
| Description: | One technical note and one user's manual (with software) containing decision keys to quantify competitive status of non-crop vegetation surrounding crop trees in the establishment to Free-to-Grow period. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Scott, L., Towill, W.D. and Edgar, G. 1991. Competition index program users manual. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TR-61. 48 p. |
| | Towill, W.D. and Archibald, D.J. 1991. A competition index methodology for northwestern Ontario. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TN-10. 12 p. |

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|---|---|
| Name: | **Critical silvics guide** |
| Description: | A pocket-sized field guide containing tables and fact sheets describing autecological characteristics of selected crop and competitor species. Information is presented within the framework of the northwestern FEC system. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Buse, L.J. and Bell, F.W. 1992. Critical silvics of selected crop and competitor species in northwestern Ontario. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. 134 p. |

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|---|---|
| Name: | **Northeast autecology guide** |
| Description: | A pocket-sized field guide containing tables and fact sheets describing autecological characteristics of selected crop and competitor species. Information is presented within the framework of the northeastern FEC system |
| Available from: | Lakehead University bookstore |
| Reference: | Arnup, R.W., Dowsley, B., Buse, L. and Bell, F.W. 1995. Field guide to the autecology of selected crop trees and competitor species in northeastern Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont. FG-005. 157 p. |

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| Name: | **Spruce tending key** |
| Description: | A report describing the development and use of a decision key to prioritize release of black spruce seedlings from competition. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Buse, L.J. and Baker, W.D. 1991a. Black spruce site quality for the Northwestern Region of Ontario. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TN-08. 4p. |

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|---|---|
| Name: | **Cone scattering key** |
| Description: | A technical note examining factors necessary for success using this regeneration method. The potential for jack pine regeneration using cone scattering is presented for each site type. |
| Available from: | Northeast Science & Technology, Timmins |
| Reference: | Boisvenue, C., Arnup, R.W. and Archibald, D.W. 1994. Cone scattering for jack pine regeneration in northeastern Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont. TN-011. 11 p. |

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| Name: | **Slash pile burning key** |
| Description: | A technical note examining options for roadside slash pile burning to minimize loss of productive land and reduce wildfire hazard. A decision key is presented to assist managers in developing burning strategies. |
| Available from: | Northeast Science & Technology, Timmins |
| Reference: | Luke, A.B., Scarlett, D.J. and Archibald, D.J. 1993. Roadside slash pile burning in northeastern Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont. TN-002. 8 p. |

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|---|---|
| Name: | **Advance growth photo-interpretive key** |
| Description: | A decision key is presented for determining the potential for black spruce advance growth using 1:20,000 black and white aerial photographs. |
| Available from: | Canadian Forest Service, Sault Ste. Marie |
| Reference: | Arnup, R.W. 1996a. Predicting the abundance of advance growth in black spruce forests in northeastern Ontario: an aerial photograph interpretive key. Ont. Min. Nat. Resour., Nat. Resour. Can., Can. For. Serv. NODA Note No. 23. 4 p. |

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|---|---|
| Name: | **Northeast advance growth key** |
| Description: | This note examines conifer advance growth relationships to FEC site types, and stand and site characteristics. A predictive key is presented to identify stands where the potential for black spruce advance growth is high. |
| Available from: | Canadian Forest Service, Sault Ste. Marie |
| Reference: | Arnup, R.W. 1996b. Site and stand factors influencing the abundance and distribution of coniferous advance growth in northeastern Ontario. Ont. Min. Nat. Resour., Nat. Resour. Can., Can. For. Serv. NODA Note No. 26. 6 p. |

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| Name: | **Black spruce site quality key** |
| Description: | A report describing a decision key relating black spruce site index to critical site factors. The key is intended for use in northwestern Ontario. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Buse, L.J. and Baker, W.D. 1991b. Determining necessity and priority for tending in young spruce plantations in northwestern Ontario. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TN-09. 3 p. |

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|---|---|
| Name: | **Silvicultural decision keys** |
| Description: | A report describing the development of a set of “Silvicultural Keys” used as a field tool to outline actions required to meet objectives in the strategic Timber Management Plan (TMP). These keys are designed to consider issues such as vegetation management alternatives, natural and artificial regeneration, species diversity and silvicultural costs. The keys are meant to complement, not replace, silvicultural ground rules contained in the TMP. Keys developed for the Brightsand and English River forests are included. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Street, P.W., Arlidge, C.J., Hollstedt, C., Bell, F.W. and Towill, W.D. 1994. Development of silvicultural keys to support integrated vegetation management decision making in forest renewal. Ont. Min. Nat. Resour., NWST, Thunder Bay, Ont. TN-28. 15 p. |

## Regenerating, Young and Mature Stages

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| Name | **Site productivity handbook** |
| Description: | A report summarizing the state-of-the-art in northwestern Ontario with respect to issues surrounding the measurement and maintenance of site quality for tree growth. Included are site index curves, growth intercepts, species soil-site comparisons, and soil-site equations for most tree species found in northwestern Ontario. |
| Available from: | Lakehead University bookstore |
| Reference | Carmean, W.H. 1997. Site quality evaluation, site quality maintenance, and site-specific management for forest land in northwest Ontario. Ont. Min. Nat. Resour., NWST, Thunder Bay, Ont. TR-105. 121 p. |

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| Name | **Conifer variable density yield tables** |
| Description: | A report describing types of yield tables, yield tables applicable to white spruce, black spruce, jack pine and red pine in Ontario, methods used to construct variable density yield tables, application of yield tables for crop planning purposes, and recommended future work. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference | Bell, F.W., Willcocks, A.J. and Kavanagh, J. 1990. Preliminary variable density yield tables for four Ontario conifers. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TR-50. 80 p. |

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| Name: | **Honer's volume equations** |
| Description: | A report describing the derivation of single tree volume tables and equations for many commercial tree species of central and eastern Canada. |
| Available from: | Canadian Forest Service - Maritimes, Fredericton, NB |
| Reference: | Honer, T.G., Ker, M.F. and Almedag, I.S. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Can. For. Serv., Maritimes For. Res. Cent. Inf. Rep. M-X-140. 42 p. |

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|---|---|
| Name: | **Northeast local volume tables** |
| Description: | A pocket-sized field guide containing local volume tables for estimating height, age, and tree volume (total, gross, and net merchantable) from an observed diameter at breast height. Data are derived from plots in natural stands in northeastern Ontario. |
| Available from: | Northeast Science & Technology, Timmins |
| Reference: | Maurer, N.L. 1993. Local volume tables for northeastern Ontario. Ont. Min. Nat. Resour., NEST, Timmins, Ont. FG-02. 101 p. |

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| Name | **Jack pine stand density diagram** |
| Description: | A report describing the development of a stand density diagram for jack pine in boreal Ontario. A number of examples are presented to show how the diagram can be used to evaluate silvicultural options for stand-level crop planning. A waterproof, pull-out diagram is included for use in the field. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference | Archibald, D.J. and Bowling, C. 1995. Jack pine density management diagram for boreal Ontario. Ont. Min. Nat. Resour., NEST/NWST, NEST TN-005, NWST TN-31. 19 p. |

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|---|---|
| Name: | **Silviculture manual** |
| Description: | A report (lab manual) summarizing many tools useful for stand-level silviculture and crop planning. Included are graphs for Wilson's Spacing Factor (based on density and tree height) and Reineke's SDI (based on density and diameter at breast height). |
| Available from: | Lakehead University Bookstore |
| Reference: | Day, R.J. 1996. Crop plans and measures of stand density relative to the -3/2 power law. IN: A manual of silviculture. Lakehead Univ. Fac. of Forestry, Thunder Bay, Ont. Lab. Man. #1, 17th ed. p 232-268. |

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|---|---|
| Name: | **ONTWIGS** |
| Description: | A report and associated software describing the adaptation of the original American program (LSTWIGS—The Woodman's Ideal Growth Simulator developed for the Lake States) including metrification and model coefficient substitution, where necessary, ONTWIGS can be used as a stand-level growth and yield projection system for boreal mixedwoods for short projection periods (5 to 10 years), and red pine plantations for 30 to 50 years. |
| Available from: | Canadian Forest Service, Sault Ste. Marie |
| Reference: | Payandeh, B., Papadopol, P. and Wang, Y. 1996. "ONTWIGS" - a forest projection system for Ontario. Nat. Resour. Can., Can. For. Serv., Sault Ste. Marie, Ont. TN-23. 3 p. |

# FOREST/LANDSCAPE-LEVEL TOOLS

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|---|---|
| Name | **Strategic Forest Management Model (SFMM)** |
| Description: | SFMM is a non-spatial forest modelling tool which allows users to analyse and represent large forested areas at a broad, strategic level. The model (PC-based software) is interactive, with graphical production capabilities. It enables the user to gain an understanding of how a forest develops through time and to explore alternative forest management strategies and trade-offs. The model is designed to be compatible with information currently available in Ontario. Enhancements of the model are ongoing, with the aim of including the ability to model habitat for a range of wildlife species, and to model tolerant hardwood forests managed under the selection silvicultural system. |
| Available from: | Rob Davis, Sault Ste. Marie (internal MNR only) OMNR, Natural Resource Information Centre, Toronto (external MNR only) |
| Reference: | Davis, R. 1997. Strategic forest management model: description and user's guide for SFMM version 1.3 (Draft). Ont. Min. Nat. Resour., For. Resour. Assess. Proj. 101 p. |

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|---|---|
| Name: | **Crop planning manual** |
| Description: | A report containing background, description and user's guide to CROPLAN and FORMANPC, programs to assist the resource manager in developing integrated forest-level management plans. Software is included with the report. |
| Available from: | Northwest Science & Technology, Thunder Bay |
| Reference: | Williams, J. 1991. Crop planning manual for northern Ontario. Ont. Min. Nat. Resour., NWOFTDU, Thunder Bay, Ont. TR-65. 101 p. + appendices. |

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| Name | **Landscape Ecological Analysis Package (LEAP)** |
| Description: | LEAP is a computer software (PC-based) package which analyses the spatial characteristics of landscape patterns. This software package analyses spatial data in various formats, such as digital Forest Resource Inventory data and satellite-image data. A complete description is available as a report. |
| Available from: | Dr. A. Perera, Ontario Forest Research Institute, Sault Ste. Marie |
| Reference: | Perera, A.H., Baldwin, D. and Schnekenburger, F. 1997. Landscape ecological analysis package (LEAP) II: User's manual (in preparation). |

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|---|---|
| Name | **Landscape Diversity Analysis (LDA)** |
| Description: | LDA is a computer program (PC-based) which generates several non-spatial indices of diversity, thereby summarizing the richness and distribution of landcover for the present forest. The program can compare the current forest with simulated scenarios using indices of diversity and ecological similarity. Details are available in a report. |
| Available from: | Ontario Forest Research Institute, Sault Ste. Marie |
| Reference: | Perera, A.H. and Schnekenburger, F. 1993. A computer program for landscape diversity analysis: LDA version 2.0. Ont. Min. Nat. Resour., For. Fragmentation and Biodiversity Project. Rep. No. 6. 25 p + appendices. |

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|---|---|
| Name | **Regional Hydro Ecological Simulation System (RHESSys)** |
| Description: | RHESSys is a landscape-level data processing and simulation system (PC-based) for predicting forest carbon and water cycling. It is used to simulate forest productivity and hydrology. The intent is to use this model to estimate net primary productivity and water yield as indicators of forest sustainability. Details are available in a report. |
| Available from: | Dr. A. Perera, Ontario Forest Research Institute, Sault Ste. Marie |
| Reference: | Band, L.E. 1995. Development of a landscape ecological model for management of Ontario's forests: phase 2- extension over an east-west gradient over the province. Ont. Min. Nat. Res., For. Fragmentation and Biodiversity Project., Rep. No. 17. 41 p + appendices. |

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|---|---|
| Name | **Socioeconomic Impact Model (SEIM)** |
| Description: | SEIM allows the user to determine the economic, social and environmental impacts of alternative forest resource uses. On-going developments and enhancements of the model (PC-based) are aimed at its use in resource management planning to detect relative socioeconomic impacts among optional management alternatives. Details are available in a report. |
| Available from: | Laurence Gravelines, OMNR, Sault Ste. Marie |
| Reference: | Econometric Research Limited. 1995. Socioeconomic impact model user’s guide, version 1.0. Ont. Min. Nat. Resour., For. Values Project. 67 p. |

# *Section V*

## Applying this Guide

This section provides guidance in applying the site-based interpretive ecological and management information contained in this guide, during the forest management planning process. This guide is only one of many sources of information to be consulted when preparing silvicultural ground rules. Local silvicultural knowledge and experience gained by members of the planning team from past management practices is equally useful.

Specifically, this section explains how interpretive information can be used to build forest units and prepare silvicultural treatment packages (STPs) for the development of silvicultural ground rules (SGRs).

## Developing Silvicultural Ground Rules

Silvicultural ground rules are specifications, standards and other instructions which direct management on management unit areas during the period of the forest management plan (OMNR 1996). Each ground rule is a unique combination of three major components:

- current forest condition;
- future forest condition; and,
- silvicultural treatment package.

Silvicultural ground rules are developed within the context of the forest-level management objectives while providing stand level direction. These rules serve as inputs to the analysis tools used to project forest development; care must be taken to select appropriate silvicultural activities to achieve the desired future forest condition.

One of the most important aspects in creating silvicultural ground rules is building ecologically based forest units.

## Building Forest Units

A forest unit is an aggregation of forest stands for management purposes which has similar species composition, develops in a similar manner (both naturally and in response to silvicultural treatments) and is managed under the same silvicultural system (OMNR 1996). While ecological factors provide the basis for defining forest units, other considerations such as economics and product requirements may also be addressed. As such, forest units are specific to the needs of each management unit.

From an ecological (i.e. stand development) perspective, derivation of forest units is generally best achieved using ecosites or site types as building blocks because the forest units will eventually be linked with specific site types or ecosites to describe current forest condition. In the absence of mapped forest ecosites or site types, forest resource inventory information (species composition, age, site class and stocking) can be integrated with local knowledge and existing sources of ecological information to build forest units. In particular, **Books II - Ecological and Management Interpretations for Northwest Ecosites,** and **III - Ecological and Management Interpretations for Northeast Site Types** summarize ecological interpretations organized by ecosite or site type that may help with this process.

Development of forest units is an iterative and adaptive process. Forest units and SGRs must be developed concurrently and the link between them and management objectives carefully considered. Results of forest-level analysis are reviewed to ensure management unit objectives will be met, and if not, forest units may have to be redefined. Forest units are created and described during the planning process as explained in the Forest Management Planning Manual (OMNR 1996).

Certain silvicultural interventions or management objectives may require forest units that do not currently exist on the landscape. For example, a management objective to re-introduce an extirpated species may generate a future forest condition not currently present on the landscape. The final list of forest units must capture all stand conditions representing the current forest as well as stand conditions which will occur in the future as a result of management actions (OMNR 1996).

## Preparing Silvicultural Treatment Packages

Silvicultural treatment packages refer to the range of acceptable treatments (harvest, renewal, tending) for the appropriate forest unit which can be undertaken at various intervals throughout the life of a forest stand to achieve a desired future forest condition (OMNR 1996). For each current forest unit/site type combination, a linear, harvest-to-harvest string of activities must be described to achieve the predicted future forest condition. Each silvicultural treatment package includes: silvicultural system, harvest method, logging method, renewal treatment(s) (site preparation and regeneration), tending treatment(s) and regeneration standards.

## Applying this Guide to Develop Silvicultural Ground Rules

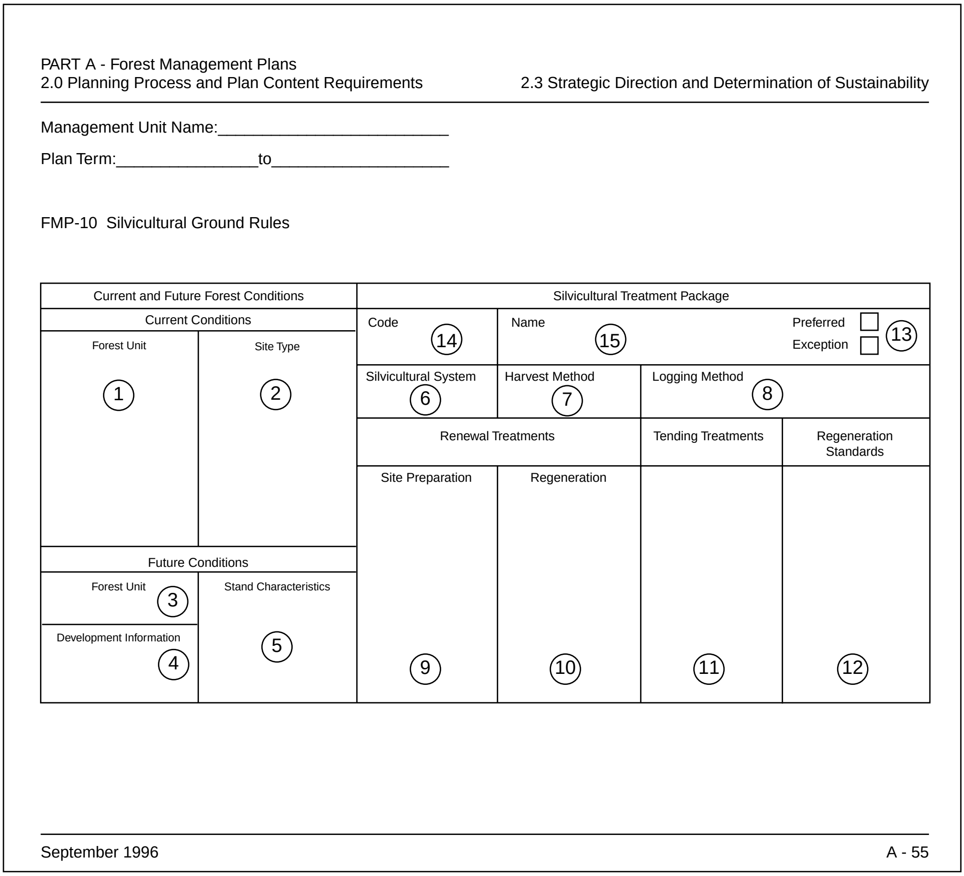
Silvicultural ground rules are documented in a series of tables included in the forest management plan (**Figure 1**). A number of components must be specified to complete the description of an SGR. Figure 1 shows each component numbered for cross-referencing to the text that follows. Where appropriate, the text refers to sections in this guide where information can be found to help complete the silvicultural ground rules table.

## Current and Future Forest Conditions

### Current Conditions

#### 1. Forest Unit

Forest units are developed as described previously in this section. **Books II** and **III** provide guidance for developing ecologically based criteria. Selected forest resource inventory parameters and criteria may be used to assign a stand to a forest unit. For example, the presence of species such as jack pine or balsam fir might be used to differentiate between upland and lowland spruce mixedwoods.



PART A - Forest Management Plans
2.0 Planning Process and Plan Content Requirements
2.3 Strategic Direction and Determination of Sustainability

Management Unit Name:_________________________

Plan Term:_______________to___________________

FMP-10 Silvicultural Ground Rules

| Current and Future Forest Conditions | | Silvicultural Treatment Package | | | |
|---|---|---|---|---|---|
| Current Conditions | | Code 14 | Name 15 | | Preferred / Exception 13 |
| Forest Unit 1 | Site Type 2 | Silvicultural System 6 | Harvest Method 7 | Logging Method 8 | |
| | | Renewal Treatments | | Tending Treatments | Regeneration Standards |
| | | Site Preparation | Regeneration | | |
| Future Conditions | | | | | |
| Forest Unit 3 | Stand Characteristics 5 | | | | |
| Development Information 4 | | 9 | 10 | 11 | 12 |

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Figure 1. Components of silvicultural ground rules table (OMNR 1996).

## 2. Site Type

Site types or ecosites are used in developing forest units and are not assigned independently or 'after the fact.' Ecosite and site type fact sheets provide key information (e.g. soil depth, moisture regime, overstorey and understorey vegetation) to best link ecosites or site types to forest units. Landscape associations, as described in **Books II** and **III,** are composed of predictable patterns and sequences of vegetation and soils associated with particular landform features on the management unit. This information may also be used to develop site type-forest unit combinations.

# Future Conditions

Silviculture, both as an art and science, is the vehicle that moves the present forest to a desired future forest condition. While there will undoubtedly be many unpredictable events that will impact the development of a stand, the role of silviculture is to set the forest on a desired development curve by taking actions before, during and after harvest.

The ability to predict the future forest condition first begins with a good understanding of the ecology of the vegetation on site and how the use of various silvicultural treatments will influence vegetation response. Both **Section II - Silvicultural Practices** and **Section III - Autecology of Forest Plants** provide general information in this regard.

### 3. Forest Unit

Depending on management objectives and silvicultural treatment packages used, a current forest unit may be directed to a variety of future forest units. For example, a current forest unit of Pj3 may be directed into future forest units Pj3 or Po2 or Sb5, depending on the specific silvicultural treatment package applied. Information in **Books II** and **III**, specifically successional pathways and management interpretations, may be used to predict future forest units. **However, an individual SGR must describe only one future forest unit.**

### 4. Development Information

Development information reflects predicted outputs from the application of each silvicultural ground rule. Typically, these are yield curves for selected tree species but, depending on the management objectives, could be yield curves for other products (e.g. browse production, snag density or lichen cover abundance).

Forest units are explicitly linked to yield curves as inputs to the analysis tools used to assess forest sustainability. The proportion of the original forest unit that will develop into the desired future forest unit after applying the STP must be determined. This is accomplished by accessing available information and the experience of the local resource manager. If less than 100 percent of the original forest unit is predicted to develop into the desired future forest unit, the other future forest units and the percentage tracking to them must also be identified and assigned to the appropriate yield curve.

In addition to the general information in Sections II and III, information in **Books II** and **III**, and **Section IV - Silvicultural Decision Tools** can assist in developing yield curves.

### 5. Stand Characteristics

Future stand characteristics must be described in terms of species composition. As a minimum, these characteristics must be described for the mature stand. In addition, species composition at other stand ages or information such as stand density or product may also be included.

Guidance on developing these descriptors can be found in **Books II** and **III**, and **Section IV.**

NOTE: **Natural Ingress Probability and Density** and **Advance Growth** tables should be considered, regardless of silvicultural treatment package. Natural regeneration of various boreal tree species will always occur on certain ecosites. Taking this into account will result in a more accurate prediction of what the future stand composition and structure characteristics will be for both naturally and artificially regenerated sites.

## Silvicultural Treatment Package

### 6. Silvicultural System

The resource manager has a choice of three silvicultural systems: clearcut, shelterwood and selection. Only one silvicultural system will be identified for each forest unit and must be the same as the one previously associated with the current forest condition. The choice of which system to use is related directly to the ecology of the tree species being managed and its capability to regenerate and grow under certain ecological conditions. **Section II** and **Books II** and **III** provide guidance on recommended silvicultural systems.

### 7. Harvest Method

Harvest method is a term used to further define or modify one of the three basic silvicultural systems, specifically the harvesting component or technique (e.g. strip clearcut). **Section II** and **Books II** and **III** provide guidance on recommended harvest methods.

NOTE: Commercial thinning treatments are identified here; refer to the discussion on commercial thinning in **Section II.**

### 8. Logging Method

The resource manager has three logging methods to choose from: full-tree, tree-length and cut-to-length/shortwood. The choice of logging method will have a direct impact on the selection of renewal treatments. **Section II** and **Books II** and **III** provide guidance on recommended logging methods.

**Ecosite and Site Type Fact Sheets** (**Books II** and **III**) provide information on stand composition, depth of organic matter, soil moisture and soil texture that, when combined with logging method, will affect associated renewal treatments such as site preparation, regeneration and tending.

**Site Characteristics, Limitations and Hazard Potential** tables in **Books II** and **III** identify site conditions that may require alternate logging methods (e.g. sites associated with steep slopes or rutting potential). When there are logging method options, indicate under what circumstances the different methods will be used (e.g. special conditions on the type of logging equipment and the season of harvest).

NOTE: **Logging Method** is the only component of a STP in which multiple options can be included.

## Renewal Treatments

Site Preparation and Regeneration are the two components of Renewal Treatments. Combinations of renewal treatments (e.g. chemical site preparation <u>followed by</u> prescribed burning) are acceptable within a silvicultural treatment package. It is not acceptable, however, to present optional treatments (e.g. chemical site preparation <u>or</u> prescribed burning) within a single silvicultural treatment package; separate silvicultural treatment packages are required.

### 9. Site Preparation

**Section II** and **Books II** and **III** provide guidance on recommended site preparation techniques.

**Books II** and **III** provide estimates on the level of advance growth associated with various ecosites and site types. The choice of site preparation technique may be affected if advance growth will be relied on to form part of the new forest stand. The **Natural Ingress Probability and Density** tables provide information on expected levels of natural ingress following harvesting. This information is related to seedbed condition and may also affect the choice of site preparation technique. Useful information regarding site preparation and reproductive strategies for competitive species is included in **Section III - Autecology of Selected Forest Plants**. Potential for site damage under certain ecological conditions is summarized in the **Site Characteristics, Limitations and Hazard Potential** tables (**Books II** and **III**).

NOTE: **Scarification** is considered a regeneration treatment (see **Section II**).

### 10. Regeneration

**Section II** describes regeneration methods as they apply to the establishment of black spruce, jack pine and aspen. **Books II** and **III** provide information on soil and vegetation characteristics that may affect the choice of regeneration method. **Advance Growth** and **Natural Ingress Probability and Density** information is provided by ecosite or site type and should be considered in the decision making process. The **Site Structure and Composition** tables provide information on potential understorey composition, advance growth occurrence and seedbed type. These are all factors that will influence the selection of regeneration methods. **Site Productivity** information, presented by site index and site class, can be used to help select species for renewal.

### 11. Tending Treatments

**Section II** and **Books II** and **III** provide guidance on recommended tending treatments. **Section III** and **Section IV - Silvicultural Decision Tools** provide more detailed information for formulating vegetation management strategies. Pre-commercial thinning (also known as juvenile spacing) is considered a tending treatment and should be identified here.

### 12. Regeneration Standards

Regeneration standards are the benchmarks for ensuring that the indicated silvicultural treatment package will begin to move the current forest unit to the desired future forest condition. As such, these standards must relate directly to the future stand characteristics and associated yield curves.

These standards are usually expressed as a minimum target density at a predetermined time of assessment. For example, if the future forest unit is expected to track on an intensive yield curve based on 1,800 stems per hectare of black spruce at time of assessment, yet actual density is 10,000 stems per hectare, then the STP is incorrect and follow-up remedial action may be required to achieve the objective. Variables such as acceptable species, minimum tree height and timing of assessment should also be indicated as part of the regeneration standard. The **Site Structure and Composition** and **Site Productivity Tables** in **Books II** and **III** provide an indication of acceptable species for a specific ecosite or site type.

A recent draft publication by the Ministry of Natural Resources, entitled Free-growing Regeneration Assessment Manual for Ontario (draft) (OMNR 1995e), uses the principle of numbers of well spaced free growing trees to express regeneration standards. This publication provides some guidance when choosing suitable benchmarks for tree height and numbers of trees per hectare at the free-to-grow stage.

### 13. Preferred and Exception

Refer to the *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996) for direction related to 'preferred silvicultural treatment package.'

Silvicultural treatment packages that contain activities that do not 'accord with the Silvicultural Guides' (i.e. are Not Recommended or are not included in this guide) may still be permissible but must be noted as an 'exception.' Further direction on 'exceptions' is found in the *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996).

### 14. Code

See *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996).

### 15. Name

See *Forest Management Planning Manual for Ontario's Crown Forest* (OMNR 1996).

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Archibald, D.J., Wiltshire, W.B., Morris, D.M. and Batchelor, B.D. 1997. Forest management guidelines for the protection of the physical environment. Version 1.0, draft. Ont. Min. Nat. Resour., 41 p.

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# Appendix 1

# Plant Species List
(Latin to Common Names)

## Trees

| | |
|---|---|
| *Abies balsamea* | Balsam fir |
| *Acer rubrum* | Red maple |
| *Acer saccharum* | Sugar maple |
| *Betula alleghaniensis* | Yellow birch |
| *Betula papyrifera* | White birch |
| *Fraxinus nigra* | Black ash |
| *Larix laricina* | Larch |
| *Picea glauca* | White spruce |
| *Picea mariana* | Black spruce |
| *Pinus banksiana* | Jack pine |
| *Pinus resinosa* | Red pine |
| *Pinus strobus* | White pine |
| *Populus balsamifera* | Balsam poplar |
| *Populus grandidentata* | Largetooth aspen |
| *Populus tremuloides* | Trembling aspen |
| *Quercus rubra* | Red oak |
| *Salix* spp. | Willow spp. |
| *Thuja occidentalis* | White cedar |
| *Ulmus americana* | White elm |

## Shrubs

| | |
|---|---|
| *Acer spicatum* | Mountain maple |
| *Alnus incana* ssp. *rugosa* | Speckled alder |
| *Alnus viridis* ssp. *crispa* | Green alder |
| *Amelanchier* spp. | Serviceberry spp. |
| *Andromeda polifolia* ssp. *glaucophylla* | Bog rosemary |
| *Arctosyaphylos uva-ursi* | Bearberry |
| *Chimaphila umbellata* | Prince's-pine |
| *Chamaedaphne calyculata* | Leatherleaf |
| *Cornus stolonifera* | Red osier dogwood |
| *Corylus cornuta* | Beaked hazel |
| *Diervilla lonicera* | Bush honeysuckle |
| *Epigaea repens* | Trailing arbutus |
| *Gaultheria hispidula* | Creeping snowberry |
| *Juniperus communis* | Common Juniper |
| *Kalmia angustifolia* | Sheep laurel |
| *Kalmia polifolia* | Pale laurel |
| *Ledum groenlandicum* | Labrador-tea |
| *Linnaea borealis* ssp. *longiflora* | Twinflower |

| | |
|---|---|
| *Lonicera canadensis* | Canada honeysuckle |
| *Lonicera involucrata* | Four-lined honeysuckle |
| *Lonicera* spp. | Honeysuckle spp. |
| *Lonicera villosa* | Northern honeysuckle |
| *Nemopanthus mucronatus* | Mountain-holly |
| *Prunus virginiana* ssp. *virginiana* | Choke cherry |
| *Ribes glandulosum* | Skunk currant |
| *Ribes hirtellum* | Wild gooseberry |
| *Ribes lacustre* | Bristly black currant |
| *Ribes* spp. | Currant and Gooseberry spp. |
| *Ribes triste* | Swamp red currant |
| *Rosa acicularis* ssp. *sayi* | Bristly wild rose |
| *Rubus idaeus* ssp. *melanolasius* | Wild red raspberry |
| *Rubus pubescens* | Dwarf raspberry |
| *Sorbus americana* | American mountain ash |
| *Sorbus decora* | Showy mountain ash |
| *Sorbus* spp. | Mountain ash spp. |
| *Vaccinium angustifolium* | Early low blueberry |
| *Vaccinium myrtilloides* | Velvetleaf blueberry |
| *Vaccinium oxycoccos* | Small cranberry |
| *Vaccinium spp.* | Blueberry |
| *Viburnum cassinoides* | Northern wild raisin |
| *Viburnum edule* | Squashberry |

## Herbs

| | |
|---|---|
| *Actaea rubra* | Red baneberry |
| *Actaea* spp. | Baneberry spp. |
| *Anemone quinquefolia* | Wood anemone |
| *Aralia nudicaulis* | Sarsaparilla |
| *Aster ciliolatus* | Ciliolate aster |
| *Aster macrophyllus* | Large-leaved aster |
| *Caltha palustris* | Marsh marigold |
| *Circaea alpina* | Smaller enchanter’s nightshade |
| *Clintonia borealis* | Blue bead lily |
| *Coptis trifolia* | Goldthread |
| *Cornus canadensis* | Bunchberry |
| *Fragaria virginiana* ssp. *virginiana* | Wild strawberry |
| *Galium triflorum* | Fragrant bedstraw |
| *Geocaulon lividum* | Northern comandra |
| *Goodyera pubescens* | Rattlesnake plantain |
| *Maianthemum canadense* | Wild lily-of-the-valley |
| *Maianthemum trifolium* | Three-leaved smilacina |
| *Melampyrum lineare* | Cow-wheat |
| *Mertensia paniculata* | Bluebells/Northern bluebells |

| | |
|---|---|
| *Mitella nuda* | Naked mitrewort |
| *Monotropa uniflora* | Indian pipe |
| *Oxalis montana* | Wood sorrel |
| *Petasites frigidus* var. *palmatus* | Sweet coltsfoot |
| *Sarracenia purpurea* | Pitcher plant |
| *Streptopus roseus* | Rose twisted-stalk |
| *Trientalis borealis* | Starflower |
| *Viola renifolia* | Kidney-leaved violet |

## Ferns

| | |
|---|---|
| *Athyrium filix-femina* | Lady fern |
| *Dryopteris carthusiana* | Spinulose shield fern |
| *Gymnocarpium dryopteris* | Oak fern |
| *Osmunda cinnamomea* | Cinnamon fern |
| *Pteridium aquilinum* | Bracken fern |

## Horsetails

| | |
|---|---|
| *Equisetum sylvaticum* | Woodland horsetail |

## Clubmosses

| | |
|---|---|
| *Lycopodium annotinum* | Interrupted clubmoss |
| *Lycopodium clavaatum* | Running club-moss |
| *Lycopodium lucidulum* | Shining clubmoss |
| *Lycopodium obscurum* | Ground pine |
| *Lycopodium* spp. | Clubmoss spp. |

## Grasses and Sedges

| | |
|---|---|
| *Calamagrostis canadensis* | Bluejoint grass |
| *Carex disperma* | Soft-leaved sedge |
| *Carex gracillima* | |
| *Carex intumescens* | Bladder sedge |
| *Carex oligosperma* | |
| *Carex pauciflora* | |
| *Carex* spp. | Sedge spp. |
| *Carex trisperma* | Three-seeded sedge |
| *Cinna latifolia* | Drooping wood reed |
| *Eriophorum vaginatum* | Cottongrass |
| *Oryzopsis asperifolia* | White-grained mountain rice |
| *Oryzopsis* spp. | Rice grass |

## Mosses

| | |
|---|---|
| *Brachythecium salaebrosum* | |
| *Brachythecium* spp. | |
| *Callidadium haldanianum* | |
| *Climacium dendroides* | Northern tree moss |
| *Dicranum fuscescens* | |
| *Dicranum polysetum* | |
| *Dicranum scoparium* | Broom moxx |
| *Drepanocladus uncinatus* | Sickle moss |
| *Drepanocladus* spp. | Sickle moss |
| *Hylocomium splendens* | Stair-step moss |
| *Mnium* spp. | Mnium spp. |
| *Plagiomnium cuspidatum* | Woodsy mnium |
| *Plagiothecium laetum* | |
| *Pleurozium schreberi* | Schreber's moss |
| *Polytrichum commune* | Common hair-cap moss |
| *Polytrichum juniperinum* | Juniper hair-cap moss |
| *Ptilium crista-castrensis* | Plume moss |
| *Rhytidiadelphus triquetrus* | Electrified cat’s tail moss |
| *Sanionia uncinatus* | Sickle moss |
| *Sphagnum angustifolium* | (Every mire’s sphagnum)* |
| *Sphagnum capillifolium=nemoreum* | Small red peat moss |
| *Sphagnum fuscum* | (Brown bog sphagnum) |
| *Sphagnum girgensohnii* | (Spruce swamp sphagnum) |
| *Sphagnum magellanicum* | (Red fat-leaved sphagnum) |
| *Sphagnum nemoreum=capillifolium* | (Lady’s tresses sphagnum) |
| *Sphagnum wulfianum* | |
| *Thuidium* spp. | Fern moss |
| *Tomenthypnum nitens* | Golden fuzzy fen moss |

## Lichens

| | |
|---|---|
| *Cladonia chlorphaea* | False pixie cup |
| *Cladonia coniocraea* | Powder horn lichen |
| *Cladina mitis* | Yellow-green lichen |
| *Cladina rangiferina* | Reindeer lichen |
| *Cladina stellaris* | Coral lichen |

## Liverworts

| | |
|---|---|
| *Bazzania trilobata* | Three-lobed liverwort |
| *Ptilidium ciliare* | |
| *Ptilidium pulcherrimum* | |

* Names in brackets are translated from the Finnish and may be useful as memory aids.

# Plant Species List
(Common to Latin Names)

## Trees

| | |
|---|---|
| Balsam fir | *Abies balsamea* |
| Balsam poplar | *Populus balsamifera* |
| Black ash | *Fraxinus nigra* |
| Black spruce | *Picea mariana* |
| Jack pine | *Pinus banksiana* |
| Larch | *Larix laricina* |
| Largetooth aspen | *Populus grandidentata* |
| Red maple | *Acer rubrum* |
| Red pine | *Pinus resinosa* |
| Red oak | *Quercus rubra* |
| Sugar maple | *Acer saccharum* |
| Trembling aspen | *Populus tremuloides* |
| White birch | *Betula papyrifera* |
| White cedar | *Thuja occidentalis* |
| White elm | *Ulmus americana* |
| White pine | *Pinus strobus* |
| White spruce | *Picea glauca* |
| Yellow birch | *Betula alleghaniensis* |

## Shrubs

| | |
|---|---|
| American mountain ash | *Sorbus americana* |
| Beaked hazel | *Corylus cornuta* |
| Bearberry | *Arctostaphylos uva-ursi* |
| Blueberry | *Vaccinium spp.* |
| Bog rosemary | *Andromeda polifolia* ssp. *glaucophylla* |
| Bristly black currant | *Ribes lacustre* |
| Bristly wild rose | *Rosa acicularis* ssp. *sayi* |
| Bush honeysuckle | *Diervilla lonicera* |
| Canada honeysuckle | *Lonicera canadensis* |
| Choke cherry | *Prunus virginiana* ssp. *virginiana* |
| Common Juniper | *Juniperus communis* |
| Creeping snowberry | *Gaultheria hispidula* |
| Currant and Gooseberry spp. | *Ribes* spp. |
| Dwarf raspberry | *Rubus pubescens* |
| Early low blueberry | *Vaccinium angustifolium* |
| Four-lined honeysuckle | *Lonicera involucrata* |
| Green alder | *Alnus viridis* ssp. *crispa* |
| Honeysuckle spp. | *Lonicera* spp. |
| Labrador-tea | *Ledum groenlandicum* |

| | |
|---|---|
| Leatherleaf | *Chamaedaphne calyculata* |
| Mountain ash spp. | *Sorbus* spp. |
| Mountain holly | *Nemopanthus mucronaatus* |
| Mountain maple | *Acer spicatum* |
| Northern honeysuckle | *Lonicera villosa* |
| Northern wild raisin | *Viburnum cassinoides* |
| Pale laurel | *Kalmia polifolia* |
| Prince's-pine | *Chimaphila umbellata* |
| Red osier dogwood | *Cornus stolonifera* |
| Serviceberry spp. | *Amelanchier* spp. |
| Sheep laurel | *Kalmia angustifolia* |
| Showy mountain ash | *Sorbus decora* |
| Small cranberry | *Vaccinium oxycoccos* |
| Speckled alder | *Alnus incana* ssp. *rugosa* |
| Squashberry | *Viburnum edule* |
| Swamp red currant | *Ribes triste* |
| Trailing arbutus | *Epigaea repens* |
| Twinflower | *Linnaea borealis* ssp. *longiflora* |
| Velvetleaf blueberry | *Vaccinium myrtilloides* |
| Wild red raspberry | *Rubus idaeus* ssp. *melanolasius* |
| Wild gooseberry | *Ribes hirtellum* |
| Willow spp. | *Salix* spp. |

## Herbs

| | |
|---|---|
| Baneberry spp. | *Actaea* spp. |
| Blue bead lily | *Clintonia borealis* |
| Bluebells/Northern bluebells | *Mertensia paniculata* |
| Bunchberry | *Cornus canadensis* |
| Cow-wheat | *Melammpyrum lineare* |
| Ciliolate aster | *Aster ciliolatus* |
| Fragrant bedstraw | *Galium triflorum* |
| Goldthread | *Coptis trifolia* |
| Indian pipe | *Monotropa uniflora* |
| Kidney-leaved violet | *Viola renifolia* |
| Large leaved aster | *Aster macrophyllus* |
| Marsh marigold | *Caltha palustris* |
| Naked mitrewort | *Mitella nuda* |
| Northern comandra | *Geocaulon lividum* |
| Pitcher plant | *Sarracenia purpurrea* |
| Rattlesnake plantain | *Goodyera pubescens* |
| Red baneberry | *Actaea rubra* |
| Rose twisted-stalk | *Streptopus roseus* |
| Sarsaparilla | *Aralia nudicaulis* |
| Smaller enchanter's nightshade | *Circaea alpina* |

| | |
|---|---|
| Starflower | *Trientalis borealis* |
| Sweet coltsfoot | *Petasites frigidus* var. *palmatus* |
| Three-leaved smilacina | *Maianthemum trifolium* |
| Wild lily-of-the-valley | *Maianthemum canadense* |
| Wild strawberry | *Fragaria virginiana* ssp. *virginiana* |
| Wood anemone | *Anemone quinquefolia* |
| Wood sorrel | *Oxalis montana* |

## Ferns

| | |
|---|---|
| Bracken fern | *Pteridium aquilinum* |
| Cinnamon fern | *Osmunda cinnamomea* |
| Lady fern | *Athyrium filix-femina* |
| Oak fern | *Gymnocarpium dryopteris* |
| Spinulose shield fern | *Dryopteris carthusiana* |

## Horsetails

| | |
|---|---|
| Woodland horsetail | *Equisetum sylvaticum* |

## Clubmosses

| | |
|---|---|
| Clubmoss spp. | *Lycopodium* spp. |
| Ground pine | *Lycopodium obscurum* |
| Interrupted clubmoss | *Lycopodium annotinum* |
| Running club-moss | *Lycopodium clavatum* |
| Shining clubmoss | *Lycopodium lucidulum* |

## Grasses and Sedges

| | |
|---|---|
| Bladder sedge | *Carex intumescens* |
| Bluejoint grass | *Calamagrostis canadensis* |
| Cottongrass | *Eriophorum vaginatum* |
| Drooping wood reed | *Cinna latifolia* |
| Rice grass | *Oryzopsis* spp. |
| Sedge spp. | *Carex* spp. |
| Soft-leaved sedge | *Carex disperma* |
| Three-seeded sedge | *Carex trisperma* |
| White-grained mountain rice | *Oryzopsis asperifolia* |

## Mosses

| | |
|---|---|
| (Brown bog sphagnum)* | *Sphagnum fuscum* |
| (Every mire's sphagnum) | *Sphagnum angustifolium* |
| (Lady's tresses sphagnum) | *Sphagnum capillifolium=nemoreum* |
| (Red fat-leaved sphagnum) | *Sphagnum magellanicum* |
| (Spruce swamp sphagnum) | *Sphagnum girgensohnii* |
| Broom moss | *Dicranum scoparium* |

| | |
|---|---|
| Common hair-cap moss | *Polytrichum commune* |
| Electrified cat’s tail moss | *Rhytidiadelphus triquetrus* |
| Fern moss | *Thuidium* spp. |
| Juniper hair-cap moss | *Polytrichum juniperinum* |
| Mnium spp. | *Mnium* spp. |
| Northern tree moss | *Climacium dendroides* |
| Plume moss | *Ptilium crista-castrensis* |
| Golden fuzzy fen moss | *Tomenthypnum nitens* |
| Schreber's moss | *Pleurozium schreberi* |
| Sickle moss | *Sanionia uncinatus* |
| Stair-step moss | *Hylocomium splendens* |
| Woodsy mnium | *Plagiomnium cuspidatum* |

## Lichens

| | |
|---|---|
| Coral lichen | *Cladina stellaris* |
| False pixie cup | *Cladonia chlorphaea* |
| Powder horn lichen | *Cladonia coniocraea* |
| Reindeer lichen | *Cladina rangiferina* |
| Yellow-green lichen | *Cladina mitis* |

## Liverworts

| | |
|---|---|
| Three-lobed liverwort | *Bazzania trilobata* |

* Names in brackets are translated from the Finnish and may be useful as memory aids.