A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario

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Preface

There have been significant advances in the understanding of, and approaches to, forestry practice since the completion of *A Silvicultural Guide for the White Pine and Red Pine Working Groups in Ontario* (Chapeski *et al.* 1989). Of particular note is the recent completion of the forest ecosystem classification systems for central and northern Ontario, and the OMNR's focus on ecological sustainability. This document will attempt to encompass much of the information that pertains to the management of Ontario's Great Lakes-St. Lawrence conifer forests.

Acknowledgments

The authors are indebted to various individuals that helped in the preparation of this guide. We are particularly indebted to the support and understanding received from our families. They are the ones that have sacrificed opportunities as we struggled to meet our deadlines. We also want to thank the following people who helped us in a myriad of ways, from fixing our computers to ordering reference material: Jamie Geauvreau, Daniel Kaminski, Lyn Thompson, Dianne Othmer, Wayne Reid, Donna Smith and Alex Gardner.

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Lastly, I am indebted to the members of the writing team for their hard work, humour, and understanding in the preparation of this guide. They are:

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MNR’s Strategic Directions and Statement of Environmental Values

The Ministry of Natural Resources (MNR) is responsible for managing Ontario’s natural resources in accordance with the statutes it administers. As the province’s lead conservation agency, 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 per cent 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 completed its Statement of Environmental Values (SEV) under the Environmental Bill of Rights (EBR). The Statement of Environmental Values is a document which describes how the purposes of the Environmental Bill of Rights 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 90’s*. The Ministry has taken this approach to its SEV because the strategic direction outlined in *MNR: Direction 90’s* reflects 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.

1.0 Introduction

1.0 Introduction

by Fred N.L. Pinto, Al S. Corlett and Brian J. Naylor

Ontarians with an interest in their forests have identified ecological sustainability as a primary goal for the management of the province's forests (Ontario Forest Policy Panel 1993). This goal dictates that management maintain large, healthy, diverse and productive forests that sustain the environmental, economic, social, and cultural well-being of Ontario. Specific strategic objectives identified by the Ontario Forest Policy Panel (1993) include the maintenance of biodiversity, protection of Ontario's natural heritage, protection of water, air, and soil quality, maintenance of employment opportunities, satisfaction of industrial and consumer wood needs, and provision of recreational opportunities. These concepts have been incorporated into *The Crown Forest Sustainability Act* (RSO 1995) which requires that the forests of Ontario be managed in a manner that maintains ecological sustainability.

Ecological sustainability must be addressed during the planning and implementation of forest management activities. Planning involves the spatial and temporal scheduling of forest management operations and is covered in detail in the *Forest Management Planning Manual for Ontario's Crown Forests* (OMNR 1996). Implementation of forest management activities involves application of silvicultural practices that address harvest, renewal, and maintenance. These activities regulate composition and structure of forest vegetation. To achieve ecological sustainability, silvicultural practices applied must regenerate commercially desirable species and improve or maintain stand quality while protecting site quality and maintaining ecological function (such as wildlife habitat). However, ecosystems are complex and our understanding is incomplete. Thus, as a precautionary approach, silvicultural practices should, to the extent possible, emulate natural disturbance agents.

This guide has been written to assist forest managers in the complex task of implementing ecologically sustainable silvicultural practices. It is part text-book, part guide and part rule-book. It serves as a source of experiential and experimental knowledge. In some cases lack of knowledge or variability in site and stand conditions precludes specific recommendations.

This guide attempts to describe both practices that are mandated (by policy or law) and those that are considered to represent best practices based on current knowledge and experience. Thus, it may be used by forest managers to help them formulate and evaluate *silvicultural ground rules* for the maintenance or restoration of Great Lakes-St. Lawrence conifer forests during preparation of a Forest Management Plan. The guide may also be used to select the appropriate silvicultural treatment package and complete a *Forest Operation Prescription*. However, this guide should be used to complement thoughtful professional practice. It is not intended to be a source of generic rules to define simplistic silvicultural prescriptions.

This guide covers silvicultural practices recommended for management of forest ecosystems dominated by white pine, red pine, white spruce, red spruce, eastern hemlock or eastern white cedar together with their associated species found in the Great Lakes-St. Lawrence Forest Region (Rowe 1972) of central Ontario. Managers interested in silviculture of tolerant hardwood or boreal tree species should refer to: *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario* or *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario*, respectively.

Silvicultural practice is applied forest ecology (Smith *et al.* 1996). The first part of this guide, **Sections 2.0** to **6.0**, provides a summary of existing information on the ecology of the Great Lakes-St. Lawrence conifer forest with focus on the dominant tree species. The second part of the guide, **Sections 7.0** to **10.0**, provides forest managers with recommended strategies and standards to achieve ecological sustainability in the conifer forest.

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2.0 Importance of the Great Lakes-St. Lawrence Conifer Forest to People

2.0 Importance of the Great Lakes-St. Lawrence Conifer Forest to People

by Martin Focken, Brian Campbell and Fred N.L. Pinto

2.1 Introduction

Smith *et al.* (1996) states that silvicultural practice is based upon social factors and also on the natural factors found in a forest. Further, they state that many of the social factors are considered in other forestry activities such as forest planning and forest policy. However, forest managers must be aware of the social factors that influence silvicultural practice, just as they must be aware of the effects of site or plant adaptations. For example, the timing of a removal cut in the uniform shelterwood silvicultural system may be selected based upon social factors as well as ecological factors.

2.2 Ecological Importance

Ecological integrity and health of Ontario's forests are of primary importance to people. Its importance is reflected in the legislative and policy framework developed to manage human activity in Crown forests. The legal framework reflects two complimentary value systems.

The first value system is people's reverence for all life. People recognize the ecological importance of forests for their inherent life-forming processes. It recognizes that forests can function without any intervention from people. It leads us to believe that people must learn to manage their activities so as not to disrupt the inherent life-giving properties of a healthy forest ecosystem.

The second value system recognizes that the quality, and possibly the existence, of human life is dependent upon healthy ecosystems, including forests. This value recognizes the inherent importance of forests to produce social and economic values.

2.3 Aesthetic and Recreational Importance

Conifer species in the Great Lakes-St. Lawrence forest, such as white pine and red pine, are a key feature of the "viewscapes" in this forest, along with topography, water, sky and other vegetation. Many people living or traveling in this forest region revere the beauty of large, old conifer trees growing in a natural setting. Research into recreational preferences confirms that whether camping, canoeing, hunting or hiking, people prefer to do so in forest landscapes that have at least some white and red pine trees (Haider 1992). People particularly enjoy forests comprised of old conifers where the understory is relatively open and "park-like". Locations along travel routes such as lakeshores and roads are favoured for a wide variety of recreational pursuits such as camping, picnicking, bird watching, wildlife viewing and part of the hiking experience (OMNR 1993).

Haider (1992) showed that the people surveyed tend to prefer old, tall trees of large diameter, with mosses, low levels of sunlight under the canopy, and natural-looking dead and decaying trees. Signs of harvesting, such as ground slash, were disliked, especially when re-arranged into windrows, and evidence of fire detracted from the perceived beauty of the forest (Rebe 1989). Haider and Carlucci (1991) also found that tourists seeking a remote outdoor experience in the North Algoma area identified “beautiful scenery” as one of the most important ingredients of that experience.

Recreation in pleasing landscapes is a social need and has significant economic value. One such growing source of income to the region is *ecotourism*. An important indicator of suitability for ecotourism is the presence of more than ten per cent white pine and red pine by basal area in conifer-dominated landscapes (Boyd *et al.* 1993). People tend to regard forests with white and red pine as wild, undisturbed and rare, and therefore as highly desirable areas for non-consumptive recreation (Old Growth Policy Advisory Committee 1993). The same report concludes that it is important to protect old-growth ecosystems (which often contain white and red pine) in order to diversify local and regional economies through tourism and other non-consumptive recreation linked to wilderness areas.

Forest-based recreation also plays an educational role. Where it raises the public understanding of forest ecosystems and their uses, land-use decision-making is likely to improve (Ontario Forest Policy Panel 1993).

2.4 Spiritual Importance

The same forests that are the site of outdoor physical activities are also a wellspring of spiritual fulfillment. Regardless of whether people are formally religious or not, a spiritual need for a near-natural environment is believed to be an important part of their strong attraction to conifer forests with large trees. The stature and longevity of large Great Lakes-St. Lawrence conifers provides visitors with a sense of permanence, strength and security. To many people, a vigorous forest supporting large conifers such as pines, represents a healthy environment and symbolizes personal health and future opportunity (OMNR 1993).

In the words of Schroeder (1992), “the tall conifers, such as pines, seem to inhabit two worlds - with their roots and bases close to the earth where they are solid and tangible, but with the tops adrift in the sky, ethereal and beyond reach.” To many who seek out Great Lakes-St. Lawrence region forests, the tall hemlocks, spruces and pines are a spiritual link between earthly life and the realm of the divine.

The First Nations of Ontario were part of the forest they lived in, and identified themselves with it in mind and body. The white pine in particular has long had spiritual and symbolic significance. Schroeder (1992) points out its central role in Iroquois legend. As the “Peace Tree”, the white pine symbolized the law which governed the League of Iroquois. Its branches represented shelter and protection in unity under the law; its roots radiating outwards represented the extension of law and peace to all Iroquois nations.

Many city-dwellers, from Toronto to Thunder Bay, find comfort in the simple knowledge that healthy forests exist in Ontario. Strikingly, it is not necessary for people to live within sight of the forest to enjoy this knowledge and sense of security. It is enough for them to know that there is a refuge of near-wilderness “out there”; a place where man’s presence is less conspicuous and “Nature” is in relative balance.

2.5 Cultural Importance

In the collective history and culture of the people of this region, no tree stands taller than the white pine. For aboriginals, at the material level, forests containing conifers were important sources of the means of survival and comfort. Significant aboriginal forest products were food and medicine. For example, cones, needles, bark and resin of white and red spruce are used as medicine (Erichsen-Brown 1979). White pine is often associated with honeysuckles (*Lonicera* spp.) on moister, fertile sites. All parts of honeysuckle are important sources of medicine for aboriginal peoples. On dry-to-moist, less fertile sites, sheep laurel *(Kalmia angustifolia* L.) is associated with white pine. Its leaves and flowers were used for medicines (Bentley and Pinto 1994).

Forests containing white and red pine in Site Regions 4E and 5E have long been favoured by aboriginal people as sites for settlements and camps, because of typical advantages like a relatively open understory and proximity to travel routes along lakes and rivers (OMNR 1993). Examples of the legacy of culturally or spiritually important features in the pine landscape ranges from spirit sites and native burial grounds to pictographs, from traditional camps to portages and trails, fish weirs and deadfall traps.

The pine timbering culture has attracted the interest of writers, artists and poets, whose work has helped weave the colour of the early days of pine timbering into our collective cultural memory and identity (McNutt 1985). In contrast to this influence, the extended “Group of Seven” artists seemed fascinated by pristine pine with backdrops of pre-settlement landscapes. Their romance with this subject has done much to sensitize Canadians to the beauty of real-life conifers, such as hemlocks, pines and spruces, in natural settings.

2.6 Economic Importance

The Great Lakes-St. Lawrence conifer forests are economically important to people for the goods and services they provide. The forest helps support a valuable market economy of timber products, tourism, and fur harvesting. The forest also supports a subsistence economy for many people that live in it. Little information is available on the subsistence economy of the Great Lakes-St. Lawrence conifer forest. Also, the exact contributions of the Great Lakes-St. Lawrence conifer forests to tourism or the fur trade are not available. Due to these limitations this section will only be able to report on the economic importance of the timber trade in Great Lakes-St. Lawrence conifers.

Historically, white pine has been the most important Great Lakes-St. Lawrence conifer species. For most of the nineteenth century, through the sale of timber berths and the collection of timber dues, white pine brought in nearly thirty per cent of all revenue collected by the provincial treasury. In fact, this was the largest single source of income for the province until the early

1900s, and to a large degree it financed schools, roads and other necessary services and functions provided by the Government of Ontario (Aird 1985). White pine was a source of shelter for the first settlers and much of the material for their comforts—literally, from pine cradle to pine coffin. Later, it brought foreign capital and led to exploration and settlement. It gave rise to industries and jobs and created transportation networks and towns (OMNR 1984).

Generally, the domestic and international demand for timber of medium and high quality is strong. This demand is increasing with strengthening international markets. Since the supply of good quality white pine timber is limited throughout its range, prices for mill-delivered white pine logs and red pine poles are high (OMNR 1993). Among timber species of the region, these prices are exceeded only by certain hardwoods that are harvested in lower quantity.

It is well-known that shortages are developing for some sawmills and that the wood supply of conifers in the Great Lakes-St. Lawrence forest region falls short of the present needs of the forest industry. In 1994-95, 500,000 cubic metres of white pine and 127,000 cubic metres of red pine were harvested in Ontario. These volumes supplied furnish to 80 mills using white pine timber and 71 mills using red pine.

Harvest levels for hemlock and cedar for 1994-95 were 9,300 cubic metres and 3,400 cubic metres respectively. The hemlock was used by 30 mills, and the cedar by 40 mills in Ontario. Harvest volumes for red and white spruce are not available, as they are combined with black spruce.

Great Lakes-St. Lawrence conifers have been used for more than their timber. Hemlock was exploited as a source of tannin for the leather trade for many years. It led to the harvest of large volumes of hemlock with little or no attempt at regeneration. It resulted in a smaller hemlock population today (Gordon 1992).

Cedar is used in small industries and for local consumption as fence posts, canoe-making, and wood-carving. Cedar boughs are used to extract oils for the cosmetic and pharmaceutical industries.

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3.0 Characteristics of the Great Lakes-St. Lawrence Conifer Forest

3.0 Characteristics of the Great Lakes-St. Lawrence Conifer Forest

by Brenda A. Chambers and Barb G. Merchant

3.1 Site

Site refers to the biotic and abiotic factors of the environment. Ecosites are site classification units which integrate vegetation, climate, landform and soils. Ecosite classifications have been developed for the central, northeastern and northwestern regions of Ontario. They are suitable units for the development of site-specific silvicultural prescriptions as described in Section 3.3 "Ecosites".

3.2 Climate

Pertinent macroclimatic data for the site regions of Ontario (***see*** FIGURE 3.0.1) are summarized in TABLE 3.0.1.

The climate in southern and northwestern Ontario is characterized by warm, dry summers. The spring and summer period is often very dry, particularly in southeastern and northwestern Ontario. In comparison, the climate of central and northeastern Ontario is characterized by cooler, moister conditions brought about by the moderating influence of the Great Lakes.

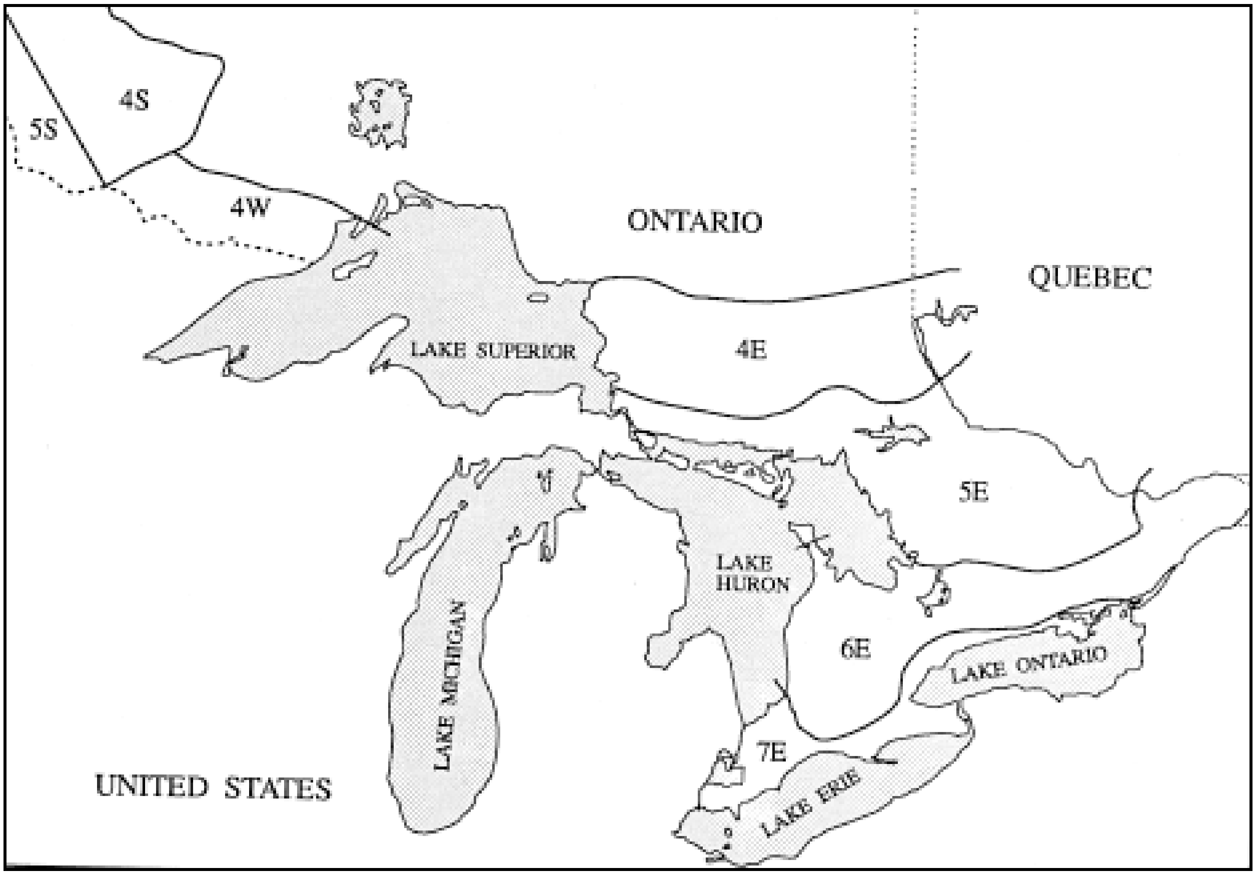
TABLE 3.0.1: Climatic data for the site regions of Ontario (*from:* MacKey *et al.* [1996])

SITE REGION	MEAN ANNUAL TEMP (°C)	AVERAGE LENGTH OF GROWING SEASON (DAYS)	AVERAGE ANNUAL PRECIPITATION (mm)	AVERAGE SUMMER RAINFALL (mm)
4S	0.1 - 2.6	174 - 188	565 - 724	245 - 291
4W	0.2 - 2.7	168 - 188	674 - 838	225 - 300
4E	0.8 - 4.3	171 - 200	725 - 1148	217 - 291
5S	1.4 - 2.8	182 - 190	557 - 712	243 - 287
5E	2.8 - 6.2	183 - 219	771 - 1134	204 - 304
6E	4.9 - 7.8	205 - 230	759 - 1087	198 - 281
7E	6.3 - 9.4	217 - 243	776 - 1018	196 - 257

3.3 Ecosites

Ecosites are classification units which reflect the interactions of vegetation, climate, landforms, soils and the effects of human activity. Natural disturbance regimes in forest ecosystems have been altered with settlement by native peoples, followed by the arrival of Europeans, with a host of land clearing and slash burning activities. In more recent history clearcut and partial cutting

FIGURE 3.0.1: Hill's Site Regions of Ontario (*from:* Hills [1959])



systems and fire exclusion have altered forest composition. With an understanding of current conditions through ecosystem classification and analysis of vegetation-environmental relationships, it is possible to make ecologically correct decisions in our management practices (e.g. in the conversion or rehabilitation of sites). Ecosites serve as the classification units for such an exercise. They are mapped at scales compatible with current planning and management activities (1:10,000 or 1: 20,000).

Ecosite classifications have been developed for the three administrative regions of Ontario (central, Chambers *et al.* 1997; northeastern, McCarthy *et al.* 1994; northwestern, Racey *et al.* 1996). Forest ecosystem classification is ongoing in southern Ontario (Lee *et al.* 1996). FIGURES 3.0.2 to 3.0.4 present ordination diagrams which plot the relative positions of ecosites along axes of fertility and moisture. Highlighted are ecosites in which white pine, red pine, white spruce, and eastern white cedar are present. Eastern hemlock and red spruce are not included in the Figures. Eastern hemlock usually occurs on central Ontario ES 28, 30 and 32, while red spruce usually occurs only on central Ontario ES 30 and 32.

FIGURE 3.0.2: Ordination diagrams for a) central Ontario, b) northeastern Ontario and c) northwestern Ontario, highlighting ecosites in which red and white pine may dominate (except northeastern Ontario, in which these species occur).

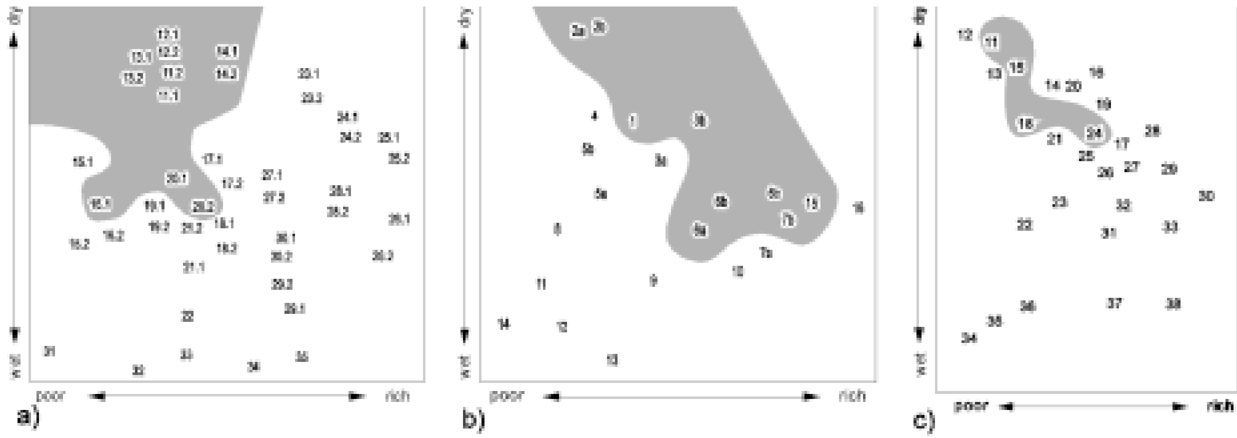


FIGURE 3.0.3: Ordination diagrams for a) central Ontario, b) northeastern Ontario and c) northwestern Ontario, highlighting ecosites in which white spruce is common (red spruce occurs in central Ontario ecosites 30 and 32).

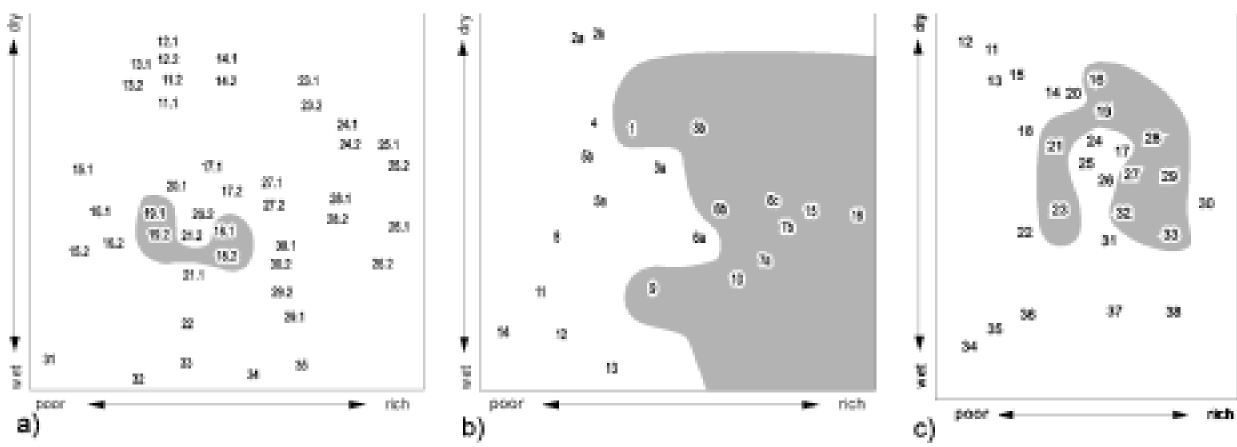
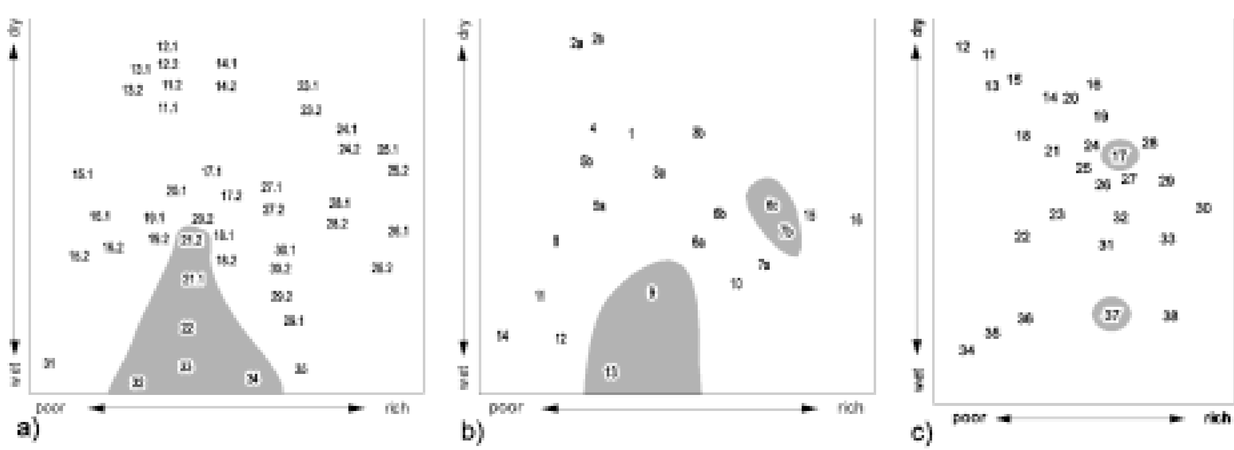


FIGURE 3.0.4: Ordination diagrams for a) central Ontario, b) northeastern Ontario and c) northwestern Ontario, highlighting ecosites in which eastern white cedar may dominate (except northeastern Ontario, in which this species occurs)



The following sections list the ecosites in which conifer species presented in this guide occur. A general description of the understory vegetation, geographic distribution, climatic data and soil-landform characteristics are provided for each ecosite. A listing of the *Field Guides* that contain detailed ecosite fact sheets are presented in APPENDIX A.

3.3.1 Central Ontario Ecosites (ES)

3.3.1.1 White pine and red pine

ES 20.1 White pine-red pine-white spruce-white birch-trembling aspen on dry to moderately fresh soils.
ES 20.2 White pine-red pine-white spruce-white birch-trembling aspen on fresh to moist soils.

This is a mixedwood pine ecosite which has a more diverse and abundant understory than ES 11, 12, 13 and 16.1. Moderate to high levels of conifer (balsam fir) and hardwood regeneration (soft maple) and tall hardwood shrubs (beaked hazel, mountain maple) are characteristic. Low hardwood shrubs include fly honeysuckle and bush honeysuckle. 59 per cent of ES 20.1 sites sampled during development of the Forest Ecosite Classification (FEC) occurred on coarse-textured soils on glaciofluvial landforms or on shallow till soils over bedrock in Site Region 4E. These sites have lower growing degree days in the growing season, lower minimum temperatures in the coldest month of the year, and occur at higher elevations than the rest of the pine-dominated ecosites (with the exception of ES 16.1) (***see*** TABLE 3.0.2). Of the sites sampled during development of the FEC, 41 per cent occurred in Site Region 5E, primarily in the Parry Sound and North Bay areas, on a similar range of soil and landform conditions. As well, 71 per cent of ES 20.2 sites sampled occurred in Site Region 5E, over half of these being in the lower elevations of the eastern half of Algonquin Park and the Ottawa Valley, on glaciofluvial and morainal landforms.

ES 14.1 White pine-largetooth aspen-red oak on dry to moderately fresh soils.
ES 14.2 White pine-largetooth aspen-red oak on fresh to moist soils.

This ecosite is predominantly in the southern and eastern part of central Ontario. It has moderate levels of hardwood (red maple, red oak, sugar maple) and conifer (balsam fir, white pine) regeneration, with tall hardwood shrubs, including beaked hazel and mountain maple, and low shrubs including wintergreen, fly honeysuckle, bush honeysuckle and blueberries. Of the sites sampled during development of the FEC, 96 per cent were in Site Region 5E; 73 per cent occurred on shallow to bedrock or moderately-deep to deep till soils. These sites have the highest growing degree days in the growing season and the highest minimum temperatures in the coldest month of the year as compared to the rest of the pine-dominated ecosites (***see*** TABLE 3.0.2).

ES 11.1 White pine-red pine on dry to moderately fresh soils.
ES 11.2 White pine-red pine on fresh to moist soils.
ES 12.1 Red pine on dry to moderately fresh soils.
ES 12.2 Red pine on fresh to moist soils.

ES 13.1 Jack pine-white pine-red pine on dry to moderately fresh soils.
ES 13.2 Jack pine-white pine-red pine on fresh to moist soils.

These ecosites are typically herb-poor, due to nutrient-poor, coarse-textured or very shallow soils, litter quality and/or climatic constraints. Feathermosses are significant, especially on the drier

sites (ES 11.1, ES 13.1). Feathermosses and associated mycorrhizal associations play a critical role in tree nutrition in such low fertility ecosites (Carleton and Arnup 1994). There are moderate levels of conifer (balsam fir, white pine) and hardwood (red maple) regeneration. Tall and low shrubs including beaked hazel, bush honeysuckle, fly honeysuckle, blueberries, wintergreen and twinflower are at moderate levels. All of these ecosites have a significant presence in Site Region 5E, on the low elevation glaciofluvial, lacustrine and bedrock-controlled landforms of the eastern part of the region (Algonquin east and the Ottawa Valley) and adjacent to Georgian Bay. Thirty per cent of ES 11.1 sites and 38 per cent of ES 13.1 sites sampled during development of the FEC occurred in Site Region 4E, on coarse-textured soils of glaciofluvial landforms or on very shallow tills over bedrock. These latter ecosites have lower growing degree days in the total growing season and lower minimum temperatures in the coldest month of the year, relative to other ecosites in this group (***see*** TABLE 3.0.2).

ES 16.1 Black spruce-pine on dry to moderately fresh soils.

This ecosite is herb-poor, and is characteristically found in the northern part of central Ontario, in Site Region 4E. There are high levels of feathermosses, and moderate levels of ericaceous shrubs including blueberries and creeping snowberry. Advance conifer regeneration is dominated by black spruce, balsam fir and white pine. This ecosite has the lowest number of growing degree days in the total growing season, the lowest minimum temperature in the coldest month of the year, and occurs at the highest elevations, as compared to the rest of the pine-dominated ecosites (***see*** TABLE 3.0.2). Typically these sites occur on very shallow till soils over bedrock, although some occur on coarse-textured soils of glaciofluvial landforms.

3.3.1.2 White spruce

ES 18.1 Poplar-white birch-white spruce-balsam fir on dry to moderately fresh soils.
ES 18.2 Poplar-white birch-white spruce-balsam fir on fresh to moist soils.

This ecosite has moderate to high levels of tall hardwood shrubs, including beaked hazel and mountain maple, and low shrubs including bush honeysuckle and fly honeysuckle. Advance conifer regeneration is dominated by balsam fir. A typical boreal mixedwood, this ecosite has a relatively low number of growing degree days in the total growing season and low minimum temperature in the coldest month of the year (***see*** TABLE 3.0.2). These sites occur in both Site Region 4E and 5E, on till soils of variable depth and on coarse and finer-textured soils of glaciofluvial and lacustrine landforms.

TABLE 3.0.2: Summary of climatic data (means) and site region allocation for central Ontario conifer ecosites

spp.	Ecosite	Minimum Temp. *coldest month* (° C)	Growing Degree Days *total growing season*	Precipitation *3 months prior to growing season* (mm)	Elevation *above sea level* (m as1)	Average Latitude (° North)	Site Region Allocation 4E (%)	Site Region Allocation 5E (%)
Pw/Pr	14.1	-19.0	1698	193	296	45.6	4	96
	14.2	-19.4	1690	190	296	45.6	4	96
	11.1	-20.7	1616	182	296	46.3	30	70
	11.2	-20.4	1645	179	277	46.1	14	86
	12.1	-20.2	1671	178	268	46.0	12	88
	12.2	-20.5	1654	178	260	46.2	19	81
	13.1	-19.9	1609	183	287	46.4	38	62
	13.2	-20.6	1618	178	303	46.1	15	85
	20.1	-21.4	1543	181	343	46.7	59	41
	20.2	-20.7	1632	175	276	46.3	29	71
	16.1	-22.2	1458	180	391	47.0	86	14
Sw	18.1	-20.8	1542	187	360	46.5	42	58
	18.2	-21.5	1570	174	293	46.7	62	38
	19.1	-22.3	1473	175	372	47.1	91	9
	19.2	-21.9	1541	178	341	46.7	53	47
He	30.1	-20.0	1568	202	381	45.9	0	100
	30.2	-20.0	1579	200	365	45.9	7	93
Ce	34	-19.8	1639	181	283	46.1	28	72
	21.1	-20.7	1632	175	277	46.3	78	22
	21.2	-20.4	1633	184	295	46.2	50	50
	32	-19.7	1602	194	314	46.1	31	69
	22	-21.1	1489	185	352	46.8	75	25
	33	-20.2	1616	187	297	46.1	35	65

ES 19.1 Poplar-jack pine-white spruce-black spruce on dry to moderately fresh soils.
ES 19.2 Poplar-jack pine-white spruce-black spruce on fresh to moist soils.

This ecosite has moderate to high levels of tall hardwood shrubs, including beaked hazel and mountain maple, and low shrubs including bush honeysuckle, low sweet blueberry and velvetleaf blueberry. Moderate levels of feathermosses, including Schreber's moss, are present at the dry end (i.e. ES 19.1). Advance conifer regeneration is dominated by balsam fir and black spruce. ES 19.1 predominantly occurs in Site Region 4E and has a low number of growing degree days in the total growing season and low minimum temperatures in the coldest month of the year (***see*** TABLE 3.0.2). ES 19.2 occurs in both Site Regions 4 and 5. Both are found on till soils of variable depth and on coarse and finer-textured soils of glaciofluvial and lacustrine landforms. White spruce is also a component in other ecosites, for example, ES 20, 22 and 33.

3.3.1.3 Eastern hemlock

ES 30.1 Eastern hemlock-yellow birch on dry to moderately fresh soils.
ES 30.2 Eastern hemlock-yellow birch on fresh to moist soils.

This ecosite has moderate levels of conifer (balsam fir, eastern hemlock) and hardwood advance regeneration (red maple, sugar maple, and yellow birch), and shrubs including striped maple, fly honeysuckle, mountain maple, beaked hazel and hobblebush. Red spruce is a minor component of this ecosite. Predominantly occurring in Site Region 5E, this ecosite is characteristic of high elevations, with high precipitation three months prior to the growing season and a low number of growing degree days in the total growing season, as compared to other conifer-dominated ecosites (***see*** TABLE 3.0.2).

3.3.1.4 Eastern white cedar

ES 34 Eastern white cedar-lowland hardwoods on very moist to wet soils.

This ecosite has a diverse *overstory* and *understory*. There are high levels of tall hardwood shrubs, including mountain maple, beaked hazel, and low shrubs including dwarf raspberry, fly honeysuckle, swamp black currant and twinflower. Regeneration includes balsam fir, eastern white cedar, red maple, sugar maple and white spruce. Occurring on a wide variety of landforms, including glaciofluvial, lacustrine, organic and morainal, 72 per cent of the FEC plots occurred in Site Region 5E. These latter sites have the highest number of growing degree days in the total growing season, as compared to other eastern white cedar-dominated ecosites (***see*** TABLE 3.0.2).

ES 21.1 Eastern white cedar-white pine-white birch-white spruce on dry to moderately fresh soils.
ES 21.2 Eastern white cedar-white pine-white birch-white spruce on fresh to moist soils.

This ecosite has moderate levels of conifer (balsam fir, eastern white cedar) and hardwood (red maple, white birch) advance regeneration, and hardwood shrubs including mountain maple, fly honeysuckle, beaked hazel and bush honeysuckle. *Sphagnum* spp., feathermosses and liverworts are present on fresh to moist sites. This ecosite occurs on a variety of landforms, including glaciofluvial and morainal, the latter of variable depth over bedrock. Seventy-eight per cent of ES 21.1 sites occurred in Site Region 4E (***see*** TABLE 3.0.2).

ES 32 Eastern white cedar-black spruce-tamarack on wet organic and fresh to moist mineral soils.

This ecosite has moderate levels of conifer regeneration (balsam fir, eastern white cedar and black spruce) and shrubs including northern wild raisin, creeping snowberry, blueberries, showy mountain ash and labrador tea. High levels of *Sphagnum* spp. and feathermosses are on the forest floor. White spruce is a minor component of this ecosite. This ecosite occurs on a variety of landforms, including glaciofluvial, lacustrine, organic and morainal. Sixty-nine per cent of the FEC plots occurred in Site Region 5E (***see*** TABLE 3.0.2).

ES 22 Eastern white cedar-other conifers on dry to moist soils.
ES 33 Eastern white cedar-other conifers on very moist to wet soils.

These ecosites have moderate levels of conifer regeneration (balsam fir, eastern white cedar and black spruce) and shrubs including mountain maple, fly honeysuckle, showy mountain ash and twinflower. Feathermosses and liverworts are at moderate levels on dry to moist soils (ES 22). Higher levels of these bryophytes are found on very moist to wet sites (ES 33) (the latter with *Sphagnum* spp.), on a wide variety of landforms. Seventy-five per cent of ES 22 sites occurred in Site Region 4E. These latter ecosites have the lowest number of growing degree days during the total growing season as compared to other eastern white cedar-dominated ecosites (TABLE 3.0.2).

3.3.2 Northwestern Ontario ecosites

Following is a list of ecosites from the northwestern Ontario forest ecosystem classifications in which red and white pine, white spruce and eastern white cedar occur.

3.3.2.1 White pine and red pine

ES 11 Red pine-white pine-jack pine: very shallow soil.
ES 15 Red pine-white pine: sandy soil.
ES 18 Red pine-white pine: fresh, coarse loamy soil.
ES 24 Red pine-white pine: fresh, fine loamy soil.

3.3.2.2 White spruce

ES 16 Hardwood-fir-spruce mixedwood: sandy soil.
ES 19 Hardwood-fir-spruce mixedwood: fresh, sandy-coarse loamy soil.
ES 21 Fir-spruce mixedwood: fresh, coarse loamy soil.
ES 23 Hardwood-fir -spruce mixedwood: moist, sandy-coarse loamy soil.
ES 27 Fir-spruce mixedwood: fresh, silty-fine loamy soil.

ES 28 Hardwood-fir-spruce mixedwood: fresh, silty soil.
ES 29 Hardwood-fir-spruce mixedwood: fresh, fine loamy-clayey soil.
ES 32 Fir-spruce mixedwood: moist, silty-clayey soil.

3.3.2.3 Eastern white cedar

ES 17 White cedar: fresh-moist, coarse-fine loamy soil.
ES 37 Rich swamp cedar (other conifer): organic soil.

3.3.3 Northeastern Ontario site types

Following is a list of ecosites from the northeastern Ontario forest ecosystem classifications in which red and white pine, white spruce and eastern white cedar occur.

3.3.3.1 White pine and red pine

ST1 Very shallow soil.
ST3b Mixedwood: coarse textured soil.
ST6b Conifer mixedwood: medium textured soil.
ST6c Hardwood mixedwood: coarse textured soil.

3.3.3.2 White spruce

ST3b Mixedwood: coarse textured soil.
ST6b Conifer mixedwood: medium textured soil.
ST6c Hardwood mixedwood: coarse textured soil.

3.3.3.3 Eastern white cedar

ST 13 Conifer-speckled alder: organic soil.

TABLE 3.0.3 provides an expert-based cross-tabulation of ecosite regional classification units. It was developed by comparing *overstory*, *understory* and soil features provided on the regional fact sheets, and relative positions of ecosites on the fertility/moisture and ordination diagrams. Blanks in TABLE 3.0.3 indicate lack of equivalency. Given the lack of time for a more quantitative approach to this exercise, ***the table should be used with caution.***

TABLE 3.0.3: Ecosite equivalency between regions*			
spp.	CENTRAL ONTARIO	NORTHWESTERN ONTARIO	NORTHEASTERN ONTARIO
Pw/Pr	ES 20.1, 20.2	ES 18, 24	-
	ES 11.1, 11.2	ES 15	-
	ES 12.1, 12.2	ES 15	-
	ES 13.1, 13.2	ES 11	-
Sw	ES 19.1, 19.2	-	ST 6c
	-	ES 27	ST 6b
Ce	ES 21.1, 21.2	ES 17	-
	ES 32	ES 37	ST 13
* Equivalencies shown in this table are approximations only, due to variation of vegetation and soils between sites.			

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3.4 Silvics of the Great Lakes-St. Lawrence Conifers

3.4 Silvics of the Great Lakes-St. Lawrence Conifers

by Fred N.L Pinto, Dave Herr and Stan Vasiliauskas

This section describes silvicultural characteristics of major conifer tree species in the Great Lakes-St. Lawrence forest region. Foresters can use this information to determine how different species will respond following forest disturbance. Silvicultural techniques will integrate this knowledge for individual species or groups of species with forest harvesting plans to ensure prompt and adequate forest regeneration.

The following silvicultural factors must be considered when carrying out sustainable management of conifers in the Great Lakes-St. Lawrence forest region.

Geographic range, and associated climate, soils and topography are crucial to tree establishment and growth. Most conifers are adapted to specific climatic and edaphic conditions. Therefore, the forester must consider whether local site, climatic, and edaphic conditions are suitable for successful management of the species in question.

Timing and physical characteristics of flowering, cone, and seed production are important to natural regeneration. Field staff must be able to recognize the various stages of flowering, cone and seed production. This will allow them to forecast the size and quality of future seed crops, and implement silvicultural operations that immediately precede or coincide with heavy natural seedfall. Seed cones are referred to as female flowers in this manual, but are also known as ovulate cones. Pollen cones are referred to as male flowers in this manual.

Periodicity of flowering and number of flowers vary according to species, genetics, tree age, vigour, crown size and exposure of the crown to full sunlight (Yeatman 1996). Also local climate and seasonal weather variation can affect all stages of seed development, from bud differentiation to seedfall.

Species differ in the length of time required to produce seed. White and red pine require 2 years to produce seed; flower buds differentiate one season before spring bud flush and pollination, followed by cone maturation and seedfall in the next season. Hemlock, cedar and spruce require 1 year to produce seed; flower buds differentiate one season before spring bud flush. Pollination and cone maturation occur during the next season.

Squirrels, and cone or seed insects can drastically reduce seed crop size. This is particularly true for non-mast years. Field staff must learn to recognize and forecast potential damage by these agents. Hedlin *et al.* (1980) and Turgeon and de Groot (1992) have published summaries of damage done by cone and seed insects. Turgeon and de Groot (1992) have published a field guide to seed and insect pests of eastern Canada.

Many factors affect seed germination and seedling establishment. Germination and early establishment are critical stages in the life history of trees. Most conifer species have specific environmental requirements for seed germination and seedling establishment. Consistent for germination of all species is a requirement for moisture, appropriate temperatures, presence of oxygen, and absence of dormancy. The GLSL conifers produce small seed whose germination is increased in shaded, sheltered microsites. Shading reduces the danger of desiccation for germinating seeds and new germinants. However, after seedlings have germinated, shading inhibits growth if light intensities are below that needed for optimal growth.

Seedlings differ in their reaction to competition from other brush and hardwood species, and susceptibility to desiccation, insect and disease damage. The following factors can affect growth and development from the seedling stage to the mature tree:

- light intensity required for optimal growth
- shade tolerance of the seedling and young sapling
- release of the overstory and tending
- effects of stand density
- inherent growth rates
- damaging agents, including fire, insects, disease and logging (***see*** Section 9.0 “Harvesting Considerations”)
- root system development.

The following sections describe silvical requirements of individual conifer species in the Great Lakes-St. Lawrence forest region. Scientific knowledge from this forest region is the basis for the discussion. When knowledge is lacking for the Great Lakes-St. Lawrence forest region, examples are provided from similar North American forest regions.

3.4.1 White pine

White pine grows under a wide variety of conditions, and is a relatively long-lived, versatile, genetically diverse, and rapidly growing tree of considerable economic and ecological value. White pine has been an important timber resource since the colonization of eastern North America.

3.4.1.1 Growing conditions for white pine

White pine grows in southeastern Canada from Newfoundland and Anticosti Island into the Maritime provinces and the Gaspé, across central and western Ontario, and west to the extreme southeast corner of Manitoba. In the United States it grows from Minnesota and Michigan, to New England and south to Georgia. The greatest concentration of white pine is in the centre of its geographic range in southern Ontario and southwestern Quebec (Horton and Brown 1960).

According to Wendel and Smith (1990) white pine grows under a wide range of climatic conditions:

- cold-dry climate of southeastern Manitoba
- cold-wet climate of Newfoundland
- warm-moist climate of the Maritimes
- warm-dry climate of southern Ontario
- July temperatures between 18° C and 23° C
- annual precipitation ranging from 510 mm to 2,030 m
- a growing season of 90 to 180 days.

White pine grows on a variety of soils and moisture conditions (***see*** FIGURES 3.4.1, 3.4.2, 3.4.3), but is most successful on medium-textured, well-drained sands or sandy loams of low to medium site quality in Ontario and the Lake States. Such sites support good white pine growth but poor hardwood growth. White pine will grow on fine sandy loams and silty loams with good to impeded drainage, provided there is no hardwood competition. White pine will not do well on heavy clay soils, poorly-drained bottom lands, or upland depressions.

FIGURE 3.4.1: Frequency and cover of white pine by soil texture based on 1,168 Forest Ecosystem Classification (FEC) plots sampled in northeastern Ontario. The white (left) outlined bar indicates the percentage of FEC plots with white pine within that texture class. The black (right) solid bar indicates the per cent cover of white pine within all plots from that texture class.

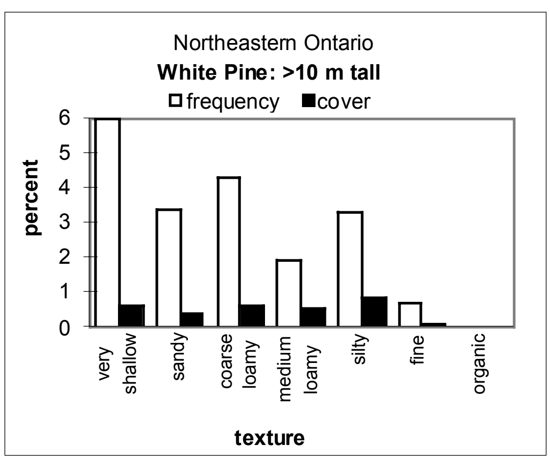


FIGURE 3.4.2: Frequency and cover of white pine by soil texture based on 2,139 FEC plots sampled in northwestern Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with white pine. The black (right) solid bar indicates the per cent cover of white pine within all plots from that texture class.

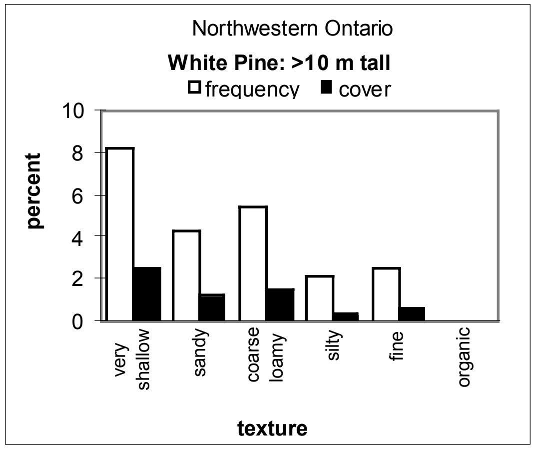
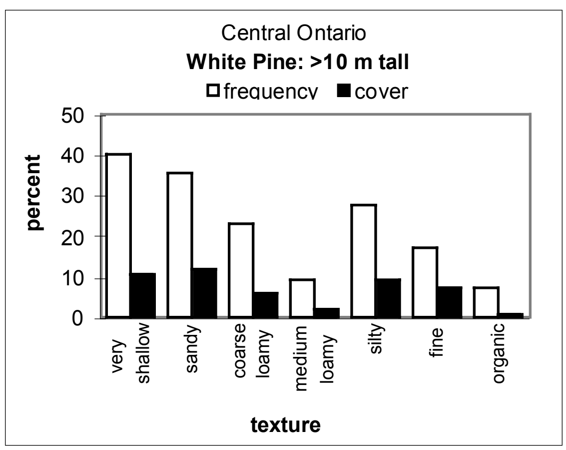


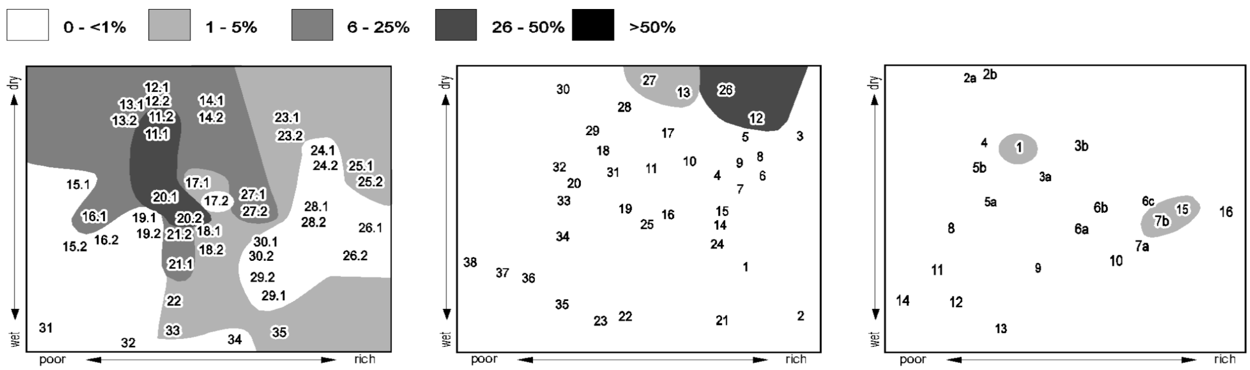
FIGURE 3.4.3: Frequency and cover of white pine by soil texture based on 1,532 FEC plots sampled in central Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with white pine. The black (right) solid bar indicates the per cent cover of white pine within all plots from that texture class.



3.4.1.2 Ecosites

White pine in central Ontario are found on a wide range of ecosites, but reach their greatest per cent cover on ecosites that are fresh to dry and medium in fertility (***see*** FIGURE 3.4.4a). In northwestern Ontario, white pine are restricted to dry but fertile vegetation types (***see*** FIGURE 3.4.4b). In northeastern Ontario its current range is even more restricted to moderately dry, moderately fertile ecosites (***see*** FIGURE 3.4.4c).

FIGURE 3.4.4: Mean per cent cover of white pine in the canopy by ecosite type and in relation to soil moisture and fertility based on FEC plots sampled in Ontario. The numbers indicate the ecosite type.



a)Central Ontario ecosite types (1,532 FEC plots)

b)Northwestern Ontario Vegetation Types (2,139 FEC plots)

c)Northeastern Ontario ecosite types (1,168 FEC plots)

3.4.1.3 White pine seed production

White pine trees are monoecious, i.e. each tree can produce male and female flowers.

Characteristics of white pine seed crops include the following:

- Tree age, cone and seed yield can begin as early as 15 years of age. Optimal cone production occurs after 50 years.

- Female cones are more common than male cones on younger trees and trees up to 30 to 60 cm DBH (Horton and Bedell 1960). Pollen cones are more common on older white pine trees.

- White pine seed production varies from year to year. Good seed crops occur every 3 to 5 years, with light seed crops during other years. Bumper seed crops may occur every 10 to 12 years. Horton and Bedell (1960) noted variation in cone production among spatially separated stands, in addition to yearly variation within stands. The following factors can affect the number of cones produced per tree and/or the number of viable seeds per cone:

- Summer temperatures affect seed crop yield. Above-average temperatures during cell differentiation is suggested as a possible cause of increased flower production in the following year.

- Stand density affects white pine cone production. Best cone output comes from large diameter, widely spaced dominant trees with full crowns (Krugman and Jenkinson 1974). Cone production is best at an intermediate stand density level of approximately 25 to 30 m^2/ha. Cone production decreases as stand density increases or decreases from this intermediate density level. Cross-pollination and subsequent seed-set are poor when residual white pine density is low.

- Individual trees can vary in cone production. Some trees are consistently good cone producers, while others are consistently poor (Wendel and Smith 1990).

- Prolonged rainy weather, fire damage, cone eating insects, red squirrels (*Tamiasciurus hudsonicus*), mice, and some birds cause seed crop loss. White pine cone crops are also susceptible to attack by the white pine cone beetle (*Conophthorus coniperda*). Turgeon (1994) suggests that white pine produces flowers and seeds almost every year, but before cones can mature, they are destroyed by insects or disease.

- Most seed falls within the first month of cone maturity. Seeds can travel 60 m within a white pine stand, and over 200 m in the open (Wendel and Smith 1990). White pine cones open best on warm fall days when there is little wind, and therefore, most seeds travel a distance equal to tree height (Horton and Bedell 1960).

3.4.1.4 White pine seed germination and establishment

Fire is essential to natural white pine regeneration (Horton and Brown 1960, Ahlgren 1976, Dickmann 1993). Fire intensities of approximately 700 kW per square metre prepare a seedbed suitable for white pine to germinate and establish, control competing vegetation, reduce cone insect populations, and open up the overstory. However, fire in young stands can kill established seedlings, therefore, the absence of fire for several decades following seedling establishment is critical.

Silvicultural treatments must provide optimal conditions to ensure prompt and adequate white pine regeneration.

For artificial regeneration by broadcast seeding, white pine requires a cold stratification period of 60 days at 2° C to 5° C to break embryo dormancy before it will germinate (Creasey and Myland 1993). Over-wintering in the soil seedbank stratifies the seeds for natural regeneration.

Successful white pine regeneration is favoured by the coincident occurrence of:

- a good seed year
- a receptive seedbed
- proper environmental conditions for the seed to germinate and the seedlings to emerge and establish.

The following physical and environmental seedbed conditions are favourable for white pine seed germination:

- Moist mineral soil or mineral soil and humus mixtures. Seedbed moisture content is a critical factor controlling success of white pine germination, emergence and establishment (Smith 1951; Herr 1996). While moist mineral soil makes a good white pine seedbed, it is not necessary for good seed germination; organic seedbeds with sufficient moisture are also suitable.
- A thin layer of *Polytrichum* moss. *Polytrichum* moss may act as a reflective surface, thereby controlling seedbed temperatures (Smith 1951). Smith (1951) noted that extensive *Polytrichum* growth may become an unfavourable seedbed.
- Burned organic horizons. Burned substrates reduce the thickness of loosely arranged litter and upper fibric horizons. These horizons tend to lose water readily through evaporation. White pine germination and establishment does not appear to be as susceptible to high ash concentrations in the seedbed substrate as red pine or jack pine (Ahlgren 1976; Herr 1996).
- Partial shade, either from slash, logging debris, or overstory cover. Partial shade over the seedbed substrate, such as that provided by a shelterwood cut, reduces evaporation and increases germination.
- A thin litter layer.
- Moderate soil surface temperatures between 20° C and 30° C.
- An adequate supply of oxygen. Along with available moisture, oxygen is critical to germination. White pine seeds may not germinate in soils wetter than field capacity because of inadequate aeration (Wendel and Smith 1990).

Unfavourable seedbed conditions for white pine seed germination include the following:

- Exposure to full sunlight. Extreme disturbances that create open, exposed environments, such as high intensity summer fires, heavy site preparation, or cut-overs can create seedbed temperatures lethal to white pine seed germination.

- Thick organic horizons. Thick, undisturbed LFH horizons are susceptible to evaporation because of the loose arrangement of litter and upper fibric horizons. Thick pine needle litter can mechanically inhibit the extension of the plumule of emerging white pine seedlings.

- Abundant shrub and herb cover, dense grass cover.

- Dry, coarse sandy soils.

- Soil pH over 8.5 (which may temporarily occur after a fire).

- Soil surface temperatures over 32° C.

White pine seedlings can establish under 20 to 25 per cent of full sunlight (Smith 1940, Atkins 1957). Seedlings will survive in as little as 7 per cent of full sunlight, although growth will not be good (Smith 1940).

Establishing seedlings are susceptible to extreme desiccation associated with high seedbed substrate temperatures (Wendel and Smith 1990). White pine seedling establishment may be best on moist mineral soil or *Polytrichum* moss because of their ability to retain moisture and moderate temperature.

Thick LFH horizons can hinder the downward growth of the radicle during the establishment phase. White pine seedlings can penetrate 5 cm of organic materials within several weeks, but thicker organic horizons may inhibit radicle growth.

Establishing white pine seedlings in the vicinity of recent forest harvest can be subject to attack by the pales weevil (*Hylobius pales*) (Wendel and Smith 1990).

3.4.1.5 White pine development from seedling to mature tree

This section describes the factors affecting development of white pine from the one-year established seedlings to the mature tree. Shelterwood silviculture is the preferred management system for white pine in Ontario (Stiell 1985). For shelterwood silviculture, forest managers must take into account white pine’s response to light intensity, competition, response to overstory thinning, and potential attack by damaging agents.

- Light is an important factor controlling white pine seedling growth, particularly when moisture is not a limiting factor (Logan 1962).
- Shade provided by slash that was beneficial to seed germination and establishment can hinder subsequent seedling growth.

- White pine seedlings are intermediate in shade tolerance (Wendel and Smith 1990).

- White pine leader growth increases with light intensity up to approximately 45 to 55 per cent of full sunlight (Logan 1959, 1966; Stiell 1985).

- Maximum leader diameter, root collar diameter and volume growth occurs at 100 per cent full sunlight (Logan 1966).

Competition from understory brush and hardwood species adversely affects white pine seedling growth (Corbett 1994):

- Young white pine seedlings are relatively slow growing for their first five years (Sims *et al.* 1990) compared to their competitive associates, and are therefore particularly susceptible to competition at these early stages.

- In an experiment involving white pine release from an aspen (*Populus tremuloides* Michx.) overstory, Logan (1962) found that removal of the competing understory significantly increased white pine seedling growth.

- Seedling growth is better when they are competing with only an overstory, rather than an overstory and an understory (Wilson and McQuilkin 1965).

- If the seedlings can survive to the sapling stage, they are more likely to survive competition from other plants and trees (Wilson and McQuilkin 1965).

- White pine competes relatively well with the light-foliage birches, and will usually gain dominance in such stands. However, in competition with the more vigorous aspens, oaks or maples, white pine will not usually gain dominance in the upper canopy, and may eventually die (Wilson and McQuilkin 1965).

- White pine in pure stands does not usually stagnate from intra-specific competition. Because of inherent variations in vigour, age, and site, white pine stratifies into different height, diameter, and crown classes.

White pine seedlings are able to survive in the full shade of a canopy for only a few years. However, they can survive in the partial shade of a canopy for longer periods of time. Foresters can manipulate light intensity at the forest floor by altering the canopy to favour white pine growth over less shade tolerant species such as white birch or bracken fern (*Pteridium aquilinum*). However, other measures such as tending with herbicides may be necessary to control more shade tolerant species such as beaked hazel (*Corylus cornuta*).

The following summary describes some responses of white pine to release:

- White pine seedlings respond well to increased light intensities by thinning of the crown cover (Rudolf 1990; Buse 1992).

- White pine will respond quickly (within two to three years) to overstory thinning if the tree is less than 30 years of age (Horton and Brown 1960).

- White pine response to release is best if at least one third of the stem is covered with foliage (Buse 1992).

Following the seedling stage, white pine growth increases at an average height increment of about 30 cm per year, assuming minimal understory competition. It is usually 1 m tall after 8 years.

The morphology of white pine root systems depends on soil characteristics:

- In most soils, three to five main roots will spread outward and downwards, and only a remnant taproot is present.

- In deeper, coarser soils, sinker roots will branch off lateral roots, and grow straight down.

- The fine feeder roots grow in the H, A, and B horizons. This is particularly true if the soil texture is fine, moisture content is high, and the soil has good structure and consistency (Wilson and McQuilkin 1965).

- Root grafting is common in white pine stands greater than about ten years old.

3.4.2 Red Pine

Red pine regeneration in the Great Lakes-St. Lawrence forest has been primarily accomplished through planting. It is used commercially by the lumber and pulpwood industries.

3.4.2.1 Growing conditions for red pine

Rudolf (1990) states that: *Red pine's range is narrow, measuring approximately 2,400 km by 800 km. It grows in isolated patches in Newfoundland, and becomes more common from Cape Breton, to southern Quebec and Ontario. Its limit extends to the southeast corner of Manitoba in the west and north along the southern fringe of the Boreal forest region. Red pine is also common in the Lake States. In the Lake States and Ontario, it is common at elevations of 240 to 430 m above sea level, and up to 1,290 m in West Virginia*.

Red pine prefers cool to warm summers, cold winters, and low to moderate precipitation. Average January temperatures vary from -18° C to -4° C and July temperatures vary from 16° C to 21° C, within its range. Average annual precipitation ranges from 500 mm to 1,000 mm and may reach up to 1,520 mm in the eastern part of the range. The frost-free growing period usually lasts from 80 to 160 days, but may be as short as 40 days northeast of Lake Superior. Red pine's northern limit closely follows the 2° C mean annual isotherm.

Larger red pine stands grow on sites that are dry, level to slightly rolling, sandy, and of low fertility (***see*** FIGURES 3.4.5, 3.4.6, 3.4.7). Red pine is usually found growing on soils that are predominantly glaciofluvial, aeolian, or lacustrine in origin. Growth is good on sub-irrigated soils with a well-aerated upper layer and a water table depth of 1 to 3 m. Red pine also grows on rock outcrops or on soils with organic debris. Growth on heavier, silt loam soils is usually poor because of competition from other species. Although it is common along borders of swamps, it rarely grows in swamps. Red pine will not grow on alkaline soils. Plantations previously established on calcareous soils start dying back after 30 years. Soil pH between 4.5 and 6.0 in the upper 25 cm allows for good growth.

FIGURE 3.4.5: Frequency and cover of red pine by soil texture based on 1,168 FEC plots sampled in northeastern Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with red pine. The black (right) solid bar indicates the per cent cover of red pine within all plots from that texture class.

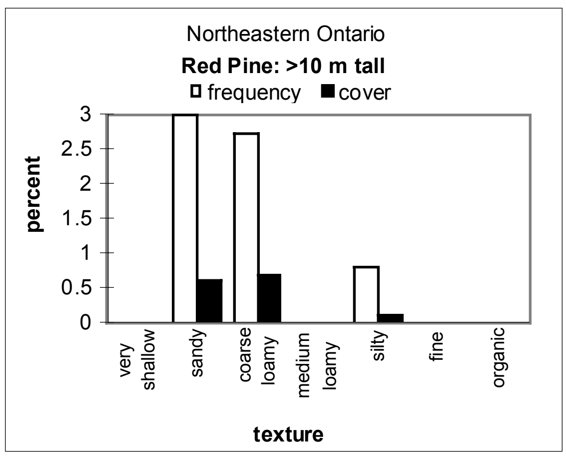


FIGURE 3.4.6: Frequency and cover of red pine by soil texture based on 2,139 FEC plots sampled in northwestern Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with red pine. The black (right) solid bar indicates the per cent cover of red pine within all plots from that texture class

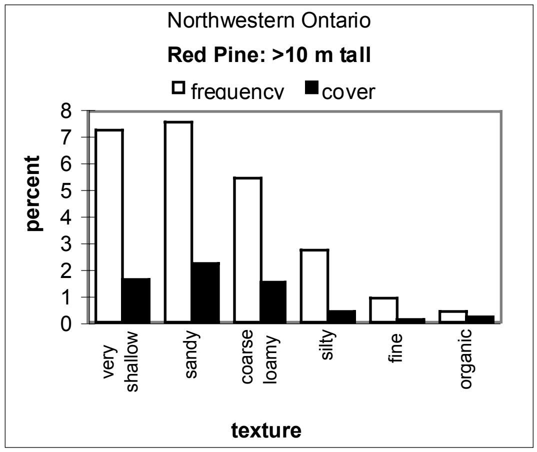
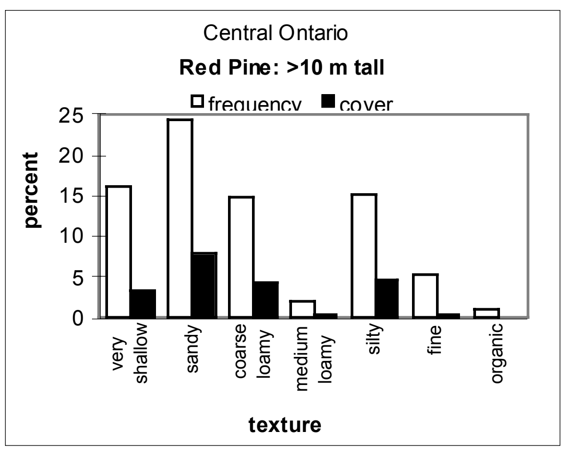


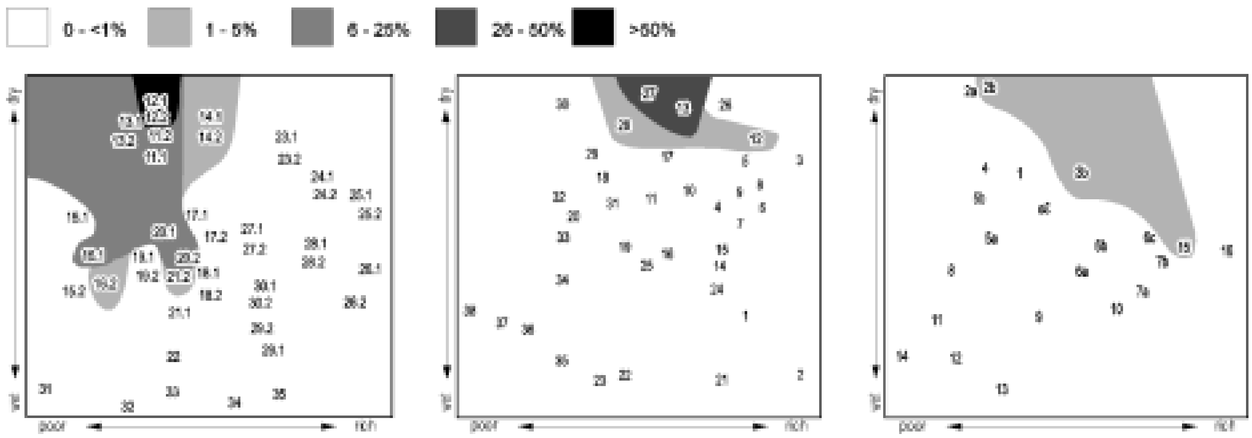
FIGURE 3.4.7: Frequency and cover of red pine by soil texture based on 1,532 FEC plots sampled in central Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with red pine. The black (right) solid bar indicates the per cent cover of red pine within all plots from that texture class.



3.4.2.2 Ecosites

Red pine in central Ontario are found on fresh to dry sites that are infertile to moderately fertile (***see*** FIGURE 3.4.8a), with their greatest abundance on dry, moderately fertile sites. In northwestern Ontario they are found on ecosites that are dry but moderately fertile to fertile (***see*** FIGURE 3.4.8b). In northeastern Ontario the per cent cover of red pine is low when present, and is restricted to fresh to dry sites with a wide range in soil fertility (FIGURE 3.4.8c).

FIGURE 3.4.8: Mean per cent cover of red pine in the canopy by ecosite and in relation to soil moisture and fertility based on FEC plots sampled in Ontario. The numbers indicate the ecosite type. Refer to Section 3.3 for ecosite type descriptions.



a)Central Ontario ecosite types (1,532 FEC plots)

b)Northwestern Ontario Vegetation Types (2,139 FEC plots)

c)Northeastern Ontario ecosite types (1,168 FEC plots)

3.4.2.3 Red pine seed production

Red pine trees are monoecious, as each tree can produce both male and female flowers. Good seed crops are infrequent, usually every 3 to 7 years. Little to no seeding occurs in the intervening years. Bumper seed crops can occur every 10 to 12 years. Cone crop yield can also vary spatially, with different yields from different stands during the same time period (Horton and Bedell 1960). The infrequency and irregularity of red pine seed crops are limiting factors affecting red pine regeneration through natural seeding (Chapeskie *et al.* 1989). Yeatman (1996) suggests that red pine flowers fairly consistently, but bumper seed crops occur only when insect and disease populations are low. The following factors can affect the number of cones produced per tree, the number of viable seeds per cone, or both:

- Emerging red pine flowers are susceptible to frost damage in the late spring. During the spring of 1980, a late frost killed most of the red pine flowers in central Ontario (Schooley *et al.* 1986).

- Summer temperatures affect seed crop output. Above-average temperatures when cones are differentiating increases cone crop yield for the following year.

- The number of cones per tree increases as stand density decreases. If seed-trees are more than 30 to 60 m apart, pollination of female cones and subsequent seed-set will be poor (Horton and Bedell 1960). Conversely, overstocked stands will have low seed cone production (Sims *et al.* 1990).
- Cone and seed yield usually begin at 15 to 25 years for open-grown red pine and 50 to 60 years for red pine in closed stands. The best seed crops occur between 50 and 150 years of age.

- Cone yield increases with crown size. Poor cone yield occurs in dense stands of short crowned trees with intermediate or suppressed crown classes.

- Cones on the upper third of the crown produce more viable seed per cone than do cones on lower portions of the crown. In addition, cones on the main branch terminals produce more viable seeds per cone than do cones on the lateral branch terminals.

- Prolonged rainy weather, fire damage, red squirrels, mice, and some birds (particularly sparrows) cause loss of seed crops. Red pine cones are susceptible to the red pine cone beetle (*Conophthorus resinosae*). Frost and drought can adversely affect cone differentiation (Horton and Bedell 1960).

3.4.2.4 Red pine seed germination and establishment

Fire is essential to natural red pine regeneration (Horton and Brown 1960, Ahlgren 1976, Dickmann 1993). Fire intensities of approximately 400 - 600 kW per metre prepare a seedbed suitable for red pine to germinate, emerge and establish, control competing vegetation, reduce cone insect populations, and open up the overstory. However, fire in young stands can kill saplings, therefore, the absence of fire for several decades following seedling establishment is critical.

For artificial regeneration by broadcast seeding, red pine requires 14 to 21 days of cold stratification to break embryo dormancy (Creasey and Myland 1993). Red pine seeds can be safely stored under dry, cold conditions for 10 years or more.

Successful red pine regeneration requires the following simultaneous events:

- a good seed year

- proper seedbed preparation

- proper environmental conditions for red pine seeds to germinate, emerge, and establish.

Favourable seedbed characteristics for red pine germination can include one or a combination of the following:

- lightly burned litter and humus

- fine, moist mineral soil

- a thin layer of *Polytrichum* moss

- a sparse covering of organic materials over the seedbed substrate

- short grass cover of light to medium density

- partial shade

- moderate soil surface temperatures between 16° C and 30° C.

Red pine germinates well when seedbed moisture content is high. A shallow water table, low sunlight levels, and/or rainfall of at least 100 mm for the months of May, June, and July encourage high moisture content. Seedbed conditions that inhibit red pine seed germination include the following:

- exposure to full sunlight

- thick LFH layers, especially the litter layer

- abundant shrub and herb cover

- soils with a pH over 5.5

- soil surface temperatures over 32° C

- dense grass cover

- rapidly drying seedbeds.

Red pine seeds do not germinate well on seedbeds with a heavy ash content. This is particularly true immediately after a fire when ash minerals have not yet been reduced by leaching (Ahlgren 1976).

After germination, red pine seedlings require at least 35 per cent of full sunlight for successful establishment (Grasovsky 1929, Shirley 1932). Establishment will likely be poor at 17 per cent or less of full sunlight.

3.4.2.5 Red pine development from seedling to mature tree

Maximum seedling height growth will occur at 45 per cent of full sunlight after the establishment period up to approximately five years of age. Shade tolerance decreases as the seedlings age. Jack pine, aspen and white birch are more shade intolerant than red pine seedlings and saplings. As a result maximum height growth of seedlings approximately 5 years or older occurs at 65 to 100 per cent of full sunlight. Here are some benchmarks for growth:

- Red pine seedlings usually take 4 to 10 years to reach breast height, or longer (16 years or more) if over-topped by competing species.

- Red pine will gain an average of 30 cm in height per year during the first 50 years of growth if unimpeded by competing species.

- From 50 to 100 years of age, height growth will average 15 cm a year, and continues to decrease to age 150, when height growth almost stops. Diameter growth, however, may continue past 150 years of age.

- Mature trees have an average height of 20 to 25 m, and up to 90 cm DBH, but can reach 46 m and 150 cm DBH. Height growth increases with site quality, but decreases with shading and insect infestations.

Diameter growth increases with increasing crown size, which in turn decreases with stand density. As stand density increases, the quantity of foliage and branch diameter decrease. As the tree ages, the rate of crown lateral expansion decreases, and stops when the canopy closes. In dense stands, red pine develops a smooth, clear bole by virtue of its excellent self-pruning properties.

Density of most red pine stands is low, but occasionally may be up to 50,000 stems per hectare. Young stands (15 to 20 years) with less than 6,000 stems per hectare become healthy, productive stands through self-thinning. Dense stands tend to stagnate, but respond well to thinning.

Taproots are present on one-year-old seedlings, particularly where a shallow water table is present. Lateral root growth, however, takes over from the taproot as the seedling ages. Lateral roots can extend 12 m beyond the crown limit, but are often shorter in denser stands.

Red pine roots develop extensive ectomycorrhizal colonizations with a variety of symbiotic soil fungi. These associations aid in mineral nutrient and soil moisture uptake. Root grafts are common in red pine stands.

3.4.3 White spruce

White spruce has the widest ecological and geographical range of any conifer species in North America (Hosie 1979). It usually grows in uneven-aged stands mixed with other tree species and rarely forms pure stands.

This valuable tree species is well adapted not only to the soil and climate conditions of the Great Lakes-St. Lawrence forest region, but also to the boreal forest of Canada. White spruce is a very adaptable species that can grow under a wide range of climatic and edaphic conditions.

3.4.3.1 Growing conditions for white spruce

Nienstaedt and Zasada (1990) state that: *White spruce is one of the wider ranging conifer species in North America. Its transcontinental range begins in Newfoundland, and runs westward along the northern tree limit in Quebec, Northwest Territories, and the Yukon. It extends south into southern British Columbia, Alberta, Manitoba, and the Lake States. White spruce grows throughout the Great Lakes-St. Lawrence forest region. It will grow at elevations ranging from sea level to 1,520 m above sea level.*

White spruce grows under a wide range of climatic conditions. At its northern limit, several factors control white spruce distribution: 1) the 10° C isotherm for mean July temperature, 2) the position of the arctic front in July, 3) mean net radiation, and 4) low light intensities (Elliot 1979). The southern limit, which forms approximately 60 per cent of the total range, roughly follows the 18° C isotherm for mean July temperature (Nienstaedt and Zasada 1990). Temperatures vary widely across its range. A January extreme of -54° C, and July extreme of 34° C were recorded at its northern limit. Mean daily temperatures vary from -29° C in January in Alaska, the Yukon, and Northwest Territories, to 21° C in July in the Lake States (Nienstaedt and Zasada 1990). Precipitation ranges from a high of 1,270 mm per year in Newfoundland and Nova Scotia, to a low of 250 mm in Alaska. Growing season varies from 180 days in Maine, to 20 days in parts of northern Canada (Nienstaedt and Zasada 1990). Growing season, however, usually exceeds 60 days in most regions (Nienstaedt 1965).

White spruce grows on a range of soils derived from a variety of landforms (***see*** FIGURES 3.4.9, 3.4.10, 3.4.11), including morainal, lacustrine, and glaciofluvial. This adaptable species will grow on both acidic and alkaline soils, with optimal soil pH ranging from 4.7 to 7.0 or higher. Podzolic soils are most common over its range. This species tolerates a range of fertility levels, with per cent nitrogen ranging from 0.01 to 0.4, and phosphorus from 2 to 10 parts per million. For best growth, white spruce requires well-aerated, moist to fresh sites, but will grow under a variety of moisture conditions.

FIGURE 3.4.9: Frequency and cover of white spruce by soil texture based on 1,168 FEC plots sampled in northeastern Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with white spruce. The black (right) solid bar indicates the per cent cover of white spruce within all plots from that texture class.

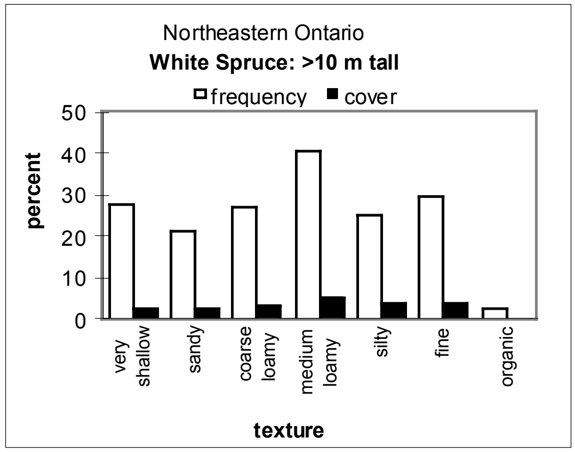


FIGURE 3.4.10: Frequency and cover of white spruce by soil texture based on 2,139 FEC plots sampled in northwestern Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with white spruce. The dark (right) black bar indicates the per cent cover of white spruce within all plots from that texture class.

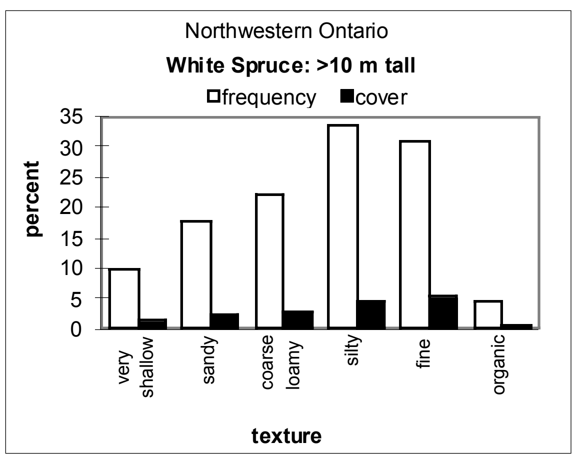
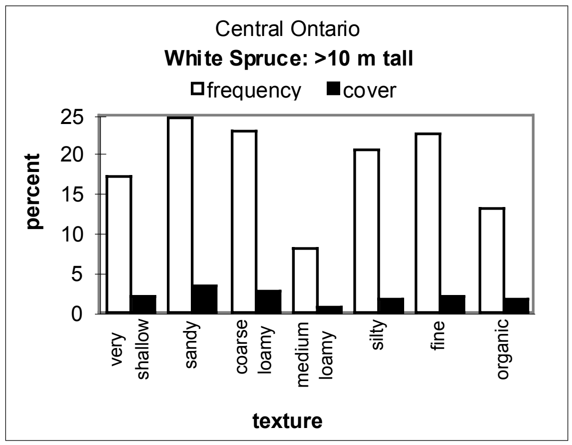


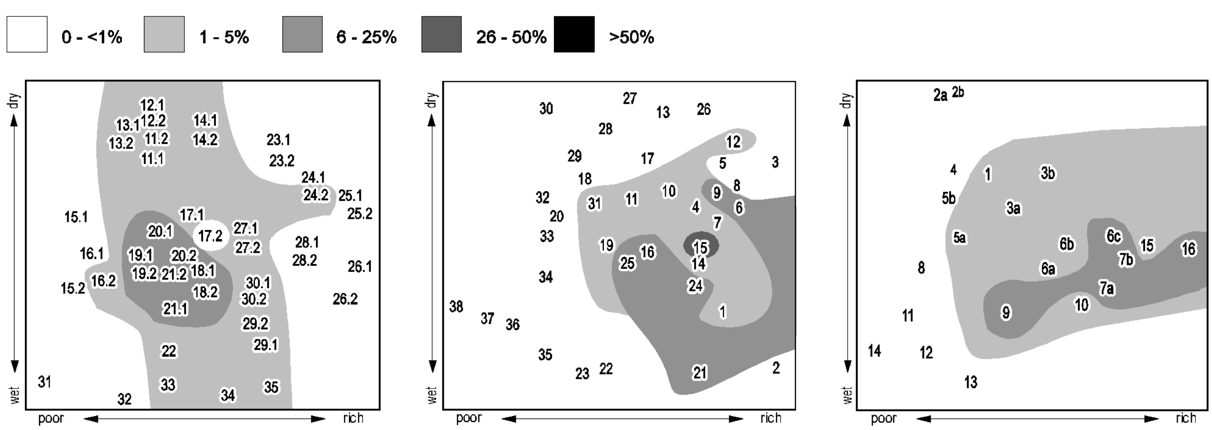
FIGURE 3.4.11: Frequency and cover of white spruce by soil texture based on 1,532 FEC plots sampled in central Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that texture class with white spruce. The black (right) solid bar indicates the per cent cover of white spruce within all plots from that texture class.



3.4.3.2 Ecosites

White spruce is found on a wide range of ecosites across the province. In central Ontario, it reaches its highest per cent cover on ecosites that are fresh and moderate in fertility (***see*** FIGURE 3.4.12a). In northern Ontario, it prefers fresh sites with soils of moderate to rich fertility (***see*** FIGURES 3.4.12b, 3.4.12c), with the highest per cent cover on fresh sites. White spruce is usually associated with balsam fir, as both species are found on similar ecosites.

FIGURE 3.4.12: Mean per cent cover of white spruce in the canopy by ecosite and in relation to soil moisture and fertility based on FEC plots in Ontario. The numbers indicate the ecosite type.



a)Central Ontario ecosite types (1,532 FEC plots)

b)Northwestern Ontario Vegetation Types (2,139 FEC plots)

c)Northeastern Ontario ecosite types (1,168 FEC plots)

3.4.3.3 White spruce seed production

White spruce is monoecious. Nienstaedt and Zasada (1990) describe the production of white spruce seed. Several factors can affect the number of cones produced per tree and the number of seeds produced per cone:

- Abnormally hot, dry weather causes increased cone differentiation from vegetative buds (Nienstaedt 1981). This is particularly true if current and preceding cone crops have been poor. The number of female buds on a tree is a good indication of cone crop size. However, this may be difficult in the early stages of differentiation as female, male, and vegetative buds look similar.

- Peak pollen release and female receptivity must coincide for best seed production. Rain or frost can adversely affect pollination and receptivity, thereby reducing seed crop size.

- The amount of pollen released varies throughout the day, and depends on temperature, wind speed, and relative humidity. Elevation can delay pollination by up to five weeks. Pollination begins earlier in southern regions than in northern regions.

- Final cone size depends on the previous year's weather, weather during cone expansion, and heredity. Cone size may vary annually.

- Seed viability is best during years of high seed production. Weather also influences seed viability. Cold growing seasons cause low seed viability.

- White spruce can begin cone production as early as 4 years of age. Production increases at 10 to 15 years of age, but large cone crops do not begin until trees are 30 years of age or older for most natural stands. Good to excellent seed crops are produced every 2 to 6 years, but can also be up to 10 to 12 years apart. Seed crop size can vary between sites and geographic location, and good seed crops are more frequent on good sites. Good seed crops are always followed by poor ones.

- Seed dispersal is weather dependent. Cool, wet, or snowy weather can delay cone opening and seed dispersal, or can cause cones to close after seed dispersal has begun. Seed dispersal will resume after drier weather returns.

- Several animals and insects can be detrimental to white spruce cone and seed crops. Squirrels can harvest up to 90 per cent of the cone crop (Zasada *et al.* 1978). Deer mice, red-backed and meadow voles, chipmunks, and shrews can eat upwards of 2,000 white spruce seeds in one day. This can have considerable impact on white spruce regeneration (Radvanyi 1974). Insects that may damage cone crops include the spruce maggot worm (*Hylemia anthracenia*), the fir coneworm (*Dioryctria abietivorella*), and the spruce seed moth (*Laspeyresia youngana*). Other insects may cause minor seed losses (see review by Nienstaedt and Zasada 1990).

3.4.3.4 White spruce seed germination and establishment

White spruce seed does not always display embryo dormancy (Fraser 1971; Wang 1976). However, stratification before artificial seeding is recommended (Creasey and Myland 1992, Nienstaedt and Zasada 1990). Cold stratification at 2° C to 5° C for 21 to 30 days will break embryo dormancy.

Optimum germination temperatures are between 10° C and 24° C. Germination will not occur below 10° C. Maximum germination temperature is between 29 ° C and 35° C. A day/night temperature fluctuation will provide the best germination results.

Seed germination begins in mid-May. Germination is usually 75 to 100 per cent completed by early June, but may last into early August. Seeds germinated after July will have a lower probability of successfully establishing then those from earlier summer.

White spruce will germinate on a variety of seedbeds:

- rotting logs (Wagg 1964) in the understory of mature forests
- feathermosses, including *Polytrichium* moss (Parker *et al.* 1997) *Hylocomium* spp. and *Pleurozium* spp. particularly in the understory of mature forests
- exposed mineral soil, either from windthrow, flooding or human disturbances.

The average number of seeds required to produce one seedling on recently exposed, moist mineral soil ranges from 5 to 30 (Eis 1967; Horton and Wang 1969; Dobbs 1976). This number should increase with the passage of time because litter and competition should increase.

Most litter seedbeds are poor germination substrates for white spruce, and may need as many as 500 to 1,000 seeds to produce one seedling (Eis 1967). This is particularly true if solar radiation is high, litter seedbeds are not disturbed, and rainfall is infrequent and sparse. White spruce seedling establishment can be limited by organic horizons greater than 5 to 8 cm in thickness.

Seedlings will not survive in less than 15 per cent full sunlight (Eis 1970). After the first year, established white spruce seedlings are 10 to 20 mm tall. The taproot usually measures 20 to 100 mm long, and lateral roots are 30 to 50 mm long.

3.4.3.5 White spruce development from seedling to mature tree

White spruce is intermediate in shade tolerance. It is less shade tolerant than red spruce, hemlock, balsam fir, hard maple and beech. White spruce is more shade tolerant than aspens or birches.

White spruce persists under the shade of broadleaf competition. The presence of competition can lead to delayed spring bud flush, which decreases white spruce's susceptibility to late spring frost damage.

At 4 to 6 years of age, white spruce can attain a height of 30 to 50 cm. At this point, the number of lateral branches and lateral root length increases significantly. White spruce usually requires 10 to 20 years to reach breast height, depending on site quality. Seedlings and saplings growing under a canopy may take as long as 40 years to reach breast height.

White spruce seedling and sapling growth rate is generally slower than its competitors. As a result, it often remains suppressed in the understory for 50 to 70 years (Day 1972). White spruce does, however, respond well to release from a very young age up to about 200 years of age (Berry 1982). Stand basal area should be between 23.0 to 32.1 m^2/ha for maximum volume growth and good tree development (Nienstaedt and Zasada 1990).

Maximum tree age varies with growing conditions. White spruce trees, 100 to 200 years old, are common on good sites. Islands or wet upland sites protected from fire may have trees 250 to 300 years of age (Juday and Zasada 1984). Trees of 500 years to almost 1,000 years grow at altitudinal or latitudinal tree lines, where trees are subjected to stress (Giddings 1962). On good sites, white spruce can grow to 30 m tall with DBH measurements greater than 1 metre.

White spruce is a shallow-rooted species, but rooting depth can vary with soil conditions, competition, and genetics. White spruce commonly grows on shallow soils which limit root depth, but has been found with multi-layered adventitious root systems on flood plains. Average rooting depth is between 90 and 120 cm. Taproots grow down to 3 m if soil conditions permit. In Ontario, 85 per cent of the root mass grows in the top 0.3 m of soil. In sandy Ontario soils, lateral roots may spread up to 18.5 m from the parent tree.

Ectomycorrhizae are common , although the diversity of species forming symbioses with white spruce is low (Stiell and Berry 1973). Root grafting is common in white spruce.

White spruce buds are susceptible to damage from extreme winter cold or late spring frost.

Spruce budworm (*Choristoneura fumiferana*) is the most damaging insect pest associated with white spruce. Spruce budworm attack is a natural occurrence associated with climax spruce forests. This insect threatens mostly older or over-mature trees, and may actually benefit younger age-classes by making more space and resources available. Because white spruce grows in uneven-aged stands, spruce budworm does not seriously threaten the species (Yeatman 1996). However, judicious, short-term spraying of biologicals during outbreaks has played (and will continue to play) an important role in extending the life of near-rotation stands until harvest. Depletion of food sources causes spruce budworm epidemics to subside. The presence of balsam fir in the stand is usually a prerequisite for a spruce budworm epidemic to occur.

Older white spruce trees are more susceptible to root rots and butt rots (Whitney 1989). Tomentosus root rot (*Inonotus tomentosus*) can cause mortality of planted white spruce seedlings (Whitney 1989). Armillaria root rot (*Armillaria* spp.) can cause deformation of the root system of planted seedlings.

3.4.4 Red Spruce

Red spruce is the least common conifer species of the Great Lakes-St Lawrence forest region. Considered equally useful as white pine, red spruce is used for making paper, construction lumber, and musical instruments (Hart 1959). Two significant red spruce declines have occurred in the past (Little 1995). The first was at the turn of the century, when over-harvesting and slash fires decreased red spruce population size. The second, more recent, decline has been documented in the United States. One or a combination of anthropogenic and natural factors may have caused this decline, including over-harvesting (Gordon 1992), atmospheric pollutants, or allelopathy (Blum 1990).

3.4.4.1 Growing conditions for red spruce

Blum (1990) states that: *The range of red spruce includes the Maritime provinces, Maine, southern Quebec and Ontario, New York, New Jersey, Massachusetts, and the Appalachian Mountains. Ontario has disjunct stands in Haliburton County, Algonquin Provincial Park, Sturgeon Falls, and in Parry Sound District. Red spruce will grow at altitudes from sea level up to 1,830 m.*

Red spruce grows in cool, moist climates. Annual precipitation ranges from 90 cm to 200 cm. Minimum January temperature range is -18° C to -13° C, and maximum July temperature range is 21° C to 27° C. Optimal red spruce growth occurs in the southern Appalachian mountains where humidity and rainfall are higher during the growing season than other parts of its range.

Red spruce is acidophilous (Gordon 1992), meaning that it will only grow on acid soils. Red spruce is common on acid, sandy loams with considerable moisture, on shallow rocky soils if hardwood competition is minimal, and on shallow organic soils overlying rock at higher elevations. The best soil characteristics include a thick mor humus with a well-defined A_2 horizon, and a soil pH of 4.0 to 5.5 (Blum 1990).

The frequency and percent cover of red spruce in the central Ontario Forest Ecosystem dataset is not presented because of low sample size.

3.4.4.2 Ecosites

Red spruce in central Ontario prefers sites with cool moist conditions. It was only found on ecosites 30.1, 30.2 and 32 in a small number of samples in the central Ontario Forest Ecosystem Classification dataset. Red spruce is not found in northwestern or northeastern Ontario. Ordination diagrams showing the percent cover of red spruce by ecosite are not presented because of low sample size.

3.4.4.3 Red spruce seed production

Red spruce is monoecious, with ovulate and pollen cones on different branches of the same tree.

Red spruce produces good seed crops every 3 to 8 years, with light seed crops in between (Hart 1965). Walter (1967) has published a formula describing the distance red spruce seeds travel as a function of tree height and wind velocity. Seeds may travel up to 100 m from the parent tree (Randall 1974).

3.4.4.4 Red spruce seed germination and establishment

Red spruce seeds germinate in late May to early June of the year following seedfall. Seeds do not last in the soil seedbank for longer than 1 year. Therefore, the seedbank will not reliably regenerate red spruce after fire or a clearcut.

To break embryo dormancy, Creasey and Myland (1992) recommend cold stratification of red spruce seed at 2° C to 5° C for 21 to 30 days. Alternately, broadcast seeding in the fall will break embryo dormancy. Not all seeds require stratification, however, as some seeds do germinate immediately after natural seeding.

Successful red spruce germination is common. A primary requirement is adequate moisture, and germination will occur on almost any moist substrate, including mineral soil, litter, humus, or rotting wood. However, mineral soil is favoured over other germination substrates because it moderates soil temperatures and provides a more constant moisture supply.

Favourable germination temperatures range from 20° C to 30° C. Seeds will not germinate below 20° C, and will be injured or die after prolonged exposure to temperatures greater than 33° C.

Germination is best under cover from a combination of light litter and at least a partial overstory canopy.

Success of red spruce regeneration depends more on first year seedling establishment and subsequent development than it does on germination (Blum 1990) because:

- establishing and established seedlings have extremely slow-growing, shallow root systems, and are vulnerable to desiccation during this period. Seedlings may not reach mineral soil if the organic horizon is greater than 5 cm.

- establishing red spruce seedlings require a minimum of 10 per cent full sunlight to survive (Blum 1990). However, 50 per cent of full sunlight allows for optimal height growth of establishing seedlings.

- hardwood litter or heavy snowfall can crush established seedlings.

- mortality of open-grown established seedlings is high if soil surface temperature reaches 46° C to 54° C, even for a short time.

- established seedlings are also vulnerable to winter drying above the snowline, causing severe leader damage, and even seedling death.

3.4.4.5 Red spruce development from seedling to mature tree

Growth of red spruce seedlings greater than 15 cm is affected by overhead competition from bracken fern, raspberry (*Rubus* spp.), and hardwood sprouts. Other competitors include trees that produce heavy shade, such as American beech, balsam fir and maples. Competition from thin crowned species such as aspen or birch is not as severe.

Height growth commences the first week of June and ends 9 to 11 weeks later. Radial growth begins about the second week in June and continues to August (Hart 1965).

Red spruce growing under ideal conditions can attain 10 cm DBH and 7 m height in 20 years, and 23 cm DBH and 19 m height in 60 years. Diameter growth is related to tree vigour, live crown ratio, live crown length, and initial diameter at breast height (McLintock 1948).

Red spruce self-prunes fairly well in dense stands. Up to one-third of the crown may be artificially pruned with no effect on future growth (Blum and Solomon 1980).

Red spruce is a shade tolerant to very shade tolerant species. Its shade tolerance varies with soil fertility and climate (Hart 1965). Red spruce shade tolerance is similar to that of balsam fir (Fowells 1965).

Light conditions strongly influence growth rate. Maximum height growth increases up to 100 per cent full sunlight (Blum 1990). However, red spruce seedlings and saplings are able to withstand severe suppression for up to 145 years and still respond to release (Frank and Bjorkbom 1973).

Suppressed trees measuring 1.2 to 1.5 m in height can be as old as 50 years. Open-grown trees of comparable age approach sawtimber size (Hart 1965).

Response to release decreases with age, and older trees may require up to 5 years to show increased growth (Brix and van den Driessche 1977).

Maximum suppression occurs when red spruce trees are growing at a rate of 2.5 cm diameter increase per 25 years over a 100 year period. Suppression causing lower growth rates will result in tree death. Balsam fir and hemlock may outgrow red spruce after release from suppression.

Red spruce is a shallow rooted species. Most feeder roots grow in the organic horizon and the first few centimetres of the mineral soil. Because of shallow root systems, no more than one-quarter or one-third of the overstory basal area should be removed in a partial cut (Blum 1990). This will minimize blowdown.

Red spruce has relatively few damaging agents:

- Due to its shallow root system, thin bark, and resinous, flammable needles, red spruce is very susceptible to fire. Fires in red spruce stands are destructive and are considered to be of little silvicultural value (Blum 1990).

- The spruce budworm (*Choristoneura fumiferana*) can attack red spruce. Red spruce may be slightly less vulnerable than the budworm's primary hosts, balsam fir and white spruce, because its buds flush later. Some damage will occur, however, if there is a high balsam fir component in red spruce forests.

- The eastern spruce beetle (*Dendroctonus rufipennis*) may damage mature spruce trees.

- Mice and voles preferentially store and consume red spruce seed over balsam fir seeds. Red squirrels clip red spruce twigs and eat vegetative and reproductive buds (Safford 1974).

3.4.5 Eastern Hemlock

Eastern hemlock has most of the features characteristic of a late successional species (Finegan 1984; Anderson *et al.* 1990). It is long-lived, grows slowly to a large size (> 1 m DBH), and is reproductively mature after 40 years, later than most conifers (Godman and Lancaster 1990). It also has features characteristic of most pioneer species, with its light, wind dispersed seeds. Individuals over 500 years are known (Anderson *et al.* 1990), and 430 years was the maximum age found in Algonquin Park (Vasiliauskas 1995).

Hemlock is important to the lumber industry and to wildlife species as browse and winter habitat (e.g. deer yards). Because of its rot resistant and durable wood, hemlock has been used in places where rot may occur. For example, hemlock from Algonquin Park was used extensively in the construction of Toronto subways.

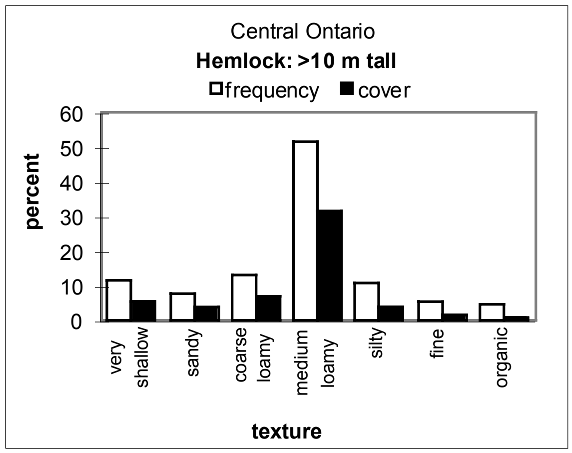
3.4.5.1 Growing conditions for eastern hemlock

Hemlock is found within the Great Lakes-St. Lawrence and Acadian forest regions of Canada (Hosie 1979) and in the northern United States from Minnesota and Wisconsin east to New England and south in the Appalachians to Tennessee and northern Alabama.

The northern limit of hemlock is coincident with its associates such as sugar maple, yellow birch and beech. Hemlock requires a growing season of at least 80 days, and a mean July temperature of at least 17° C (Goodmam and Lancaster 1990). The western range is limited to areas with at least 700 mm annual precipitation and the presence of a moist rooting environment (Rogers 1978; Kavanagh and Kellman 1986).

Hemlock stands are usually more frequent on cooler and drier, moderate to steep north and west facing slopes in Algonquin Park, and less frequent on warmer east aspect and knoll sites (Kavanagh and Kellman 1986). However, wide variation in slope aspects exists among different hemlock stands (Rogers 1978). Hemlock can grow on a wide range of soils and moisture regimes. These include dry soils on upper slopes to fresh, moist and very moist soils on lower slopes, lowlands and lakeshores. Good drainage is important. Soil textures can range from the rocky acid soils characteristic of the Canadian Shield, to loamy sands, sandy loams, silt loams, limestone soils, and even clay loams in southern Ontario (Anderson *et al.* 1990). The frequency and per cent cover of hemlock in the central Ontario Forest Ecosystem dataset is shown in FIGURE 3.4.13. Hemlock stands, if they occured, were not sampled during the preparation of the FEC in northeastern and northwestern Ontario.

FIGURE 3.4.13: Frequency and per cent cover of hemlock >10 m tall by soil texture class based on 1,532 FEC plots sampled in central Ontario. The white (left) outlined bar indicates the percentage of FEC plots within that soil texture class with hemlock present. The black (right) solid bar indicates the per cent cover of hemlock across all plots within that texture class.



3.4.5.2 Ecosites

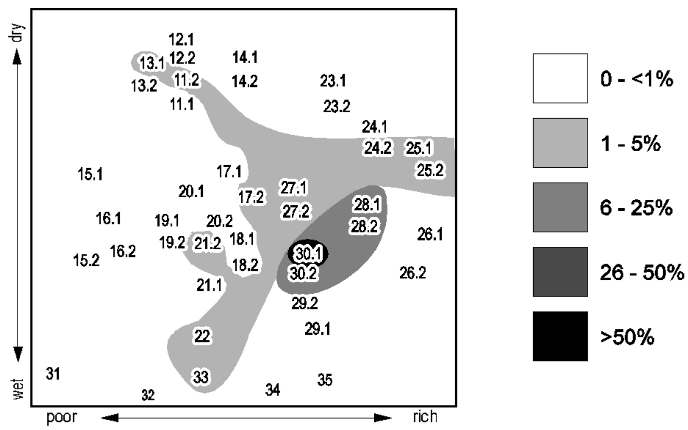
Hemlock in central Ontario has the greatest per cent cover on ecosites that are fresh and moderately fertile. It is also found on sites that are dry to wet and moderately fertile to rich (***see*** FIGURE 3.4.14)

3.4.5.3 Eastern hemlock seed production

Hemlock is monoecious, with small cones 15 to 30 mm in length (Krussman 1985). The cones are produced in the spring, mature in the same year, and shed small, winged seeds during dry weather in the fall and early winter. The cones can persist on the tree into the second year (Fowells 1965, Krussman 1985; Godman and Lancaster 1990). Wind pollination of the ovules occurs within 2 weeks of bud burst and fertilization within 6 weeks of pollination. The seeds are 1.6 mm long.

Seeds usually fall within 1 tree height of the parent tree because of eastern hemlock's small seed wings. Seeds can, however, drift on crusted snow for up to 1 km (Anderson *et al.* 1990; Godman and Lancaster 1990).

FIGURE 3.4.14: Mean per cent cover of hemlock in the canopy by ecosite and in relation to soil moisture and fertility based on 1,532 FEC plots sampled in central Ontario. The numbers indicate the ecosite type.



a)Central Ontario ecosite types
(1,532 FEC plots)

Seed production starts at about 40 years and can continue for the next 4 centuries. Adequate seed production is usually not a problem, as good cone crops in eastern hemlock occur quite frequently. Successive good crops occurred for one 5-year period, while poor crops only occurred for a maximum of 2 consecutive years (Godman and Lancaster 1990). Suppressed trees may never fruit (Anderson *et al.* 1990).

3.4.5.4 Eastern hemlock seed germination and establishment

- Hemlock seeds require 60 to 90 days of cold stratification to break embryo dormancy (Creasey and Myland 1992). Typical germinative capacity is 30 per cent (Anderson *et al.* 1990). Seeds do not last longer than one year in the soil seedbank (Mladenoff 1990).

- Germination is usually not a problem as long as there is adequate moisture and warmth. A temperature of 15° C is optimal for germination of hemlock seeds (Fowells 1965; Godman and Lancaster 1990). Seeds are easily damaged by drying. Germination is better under low rather than high light levels (Coffman 1978).

- Moist mineral soils are good germination substrates. Other ideal substrates include rotten logs, stumps, mounds and moss mats that are warmer, moister, and have less litter than the surrounding forest floor (Goder 1961).

- Germination is poor on undisturbed sites with a thick, dry organic layer.

- Hemlock stands usually have a large component of even-aged trees with older age-classes that provide shelter for the next generation. In Pennsylvania, hemlock rarely germinated and established in open areas, and few seedlings germinated under an open canopy because of moisture stress (Godman and Lancaster 1990). Germination was good on site-prepared microsites under a young canopy, especially on north slopes.

The following points summarize the conditions necessary for hemlock seedling establishment:

- For seedling establishment, a warm, moist site is necessary (Coffman 1978; Godman and Lancaster 1990). At least a partial overstory is necessary for seedling establishment.

- Hemlock seedlings are relatively small and slow-growing. They have 3 to 6 seed leaves and usually grow 25 to 38 mm in height with roots penetrating 13 mm into the soil in the first year. Because of their small size, they are easily smothered by hardwood litter (Anderson *et al.* 1990).

- Seedlings are often abundant on rotting logs, because competition from broad-leaved vegetation is minimal. Logs also retain moisture for longer periods of time than most other seedbeds.

- Variability in hemlock regeneration in the Shawanaga deeryards near Parry Sound, Ontario was due to variation in cover, drainage, aspect, depth of the "Ae" horizon, depth to bedrock, and humus depth. Optimal regeneration was on shallow, moist sites with a north or northwest aspect, some canopy openings, a thin humus layer and thin Ae horizon (Thurston and Howell 1973). Graham (1941) considered hemlock reproduction as sporadic in Wisconsin. Vasiliauskas (1995) suggests that it is more continuous on a regional scale, and dependent on stand age and conditions.

- Sugar maple can hinder hemlock establishment and over time can dominate in old growth hemlock stands (Coffman 1978).

3.4.5.5 Eastern hemlock development from seedling to mature tree

Hemlock seedlings and saplings are considered more shade tolerant than all their competitive associates. Seedlings and saplings are able to photosynthesize at very low light levels.

Hemlock usually lags behind most species in height growth. After establishment, height growth can be as slow as 1 to 2 cm per year. Slow growth is usually caused by suppression from an existing canopy. Here are some observations about growth from other reports:

- Height growth increases after the second year, following further root development. (Hosie 1979; Godman and Lancaster 1990).

- Height growth begins in mid-May and continues until late August (Anderson *et al.* 1990).

- Growth can be up to 45 cm per year for vigorous saplings in full sunlight (Anderson *et* *al.* 1990). Once the seedlings are 1 m tall, they can take 8 years on average to grow to 2 m, and another 6 years on average to grow to 3 m (Vasiliauskas 1997).

- In the Shawanaga deeryard near Parry Sound, optimal hemlock seedling growth occurred in areas with minimal deciduous basal area, a shallow Ae horizon, and little clay in the C horizon (Thurston and Howell 1973).

- Understory development can be slow, as the stem exclusion stage can limit regeneration for at least 100 years after stand establishment (Vasiliauskas 1995).

- Hemlock seedling density increases as stand age increases.

Several researchers have worked on optimal light conditions for hemlock as well as the effects of release:

- Optimal seedling height growth occurs at 50 to 55 per cent of full sunlight or greater (Logan 1973), with the slowest growth at 20 per cent of full sunlight or lower (Vasiliauskas 1997).

- Hemlock does not form root or stump sprouts, and only rarely is layering encountered (Fowells 1965; Godman and Lancaster 1990).

- Canopy stratification can start 30 years after a disturbance when hemlock and hardwood saplings are growing together. The result is a hardwood overstory and hemlock sub-canopy. Height growth of the understory hemlock is limited by breakage of shoots against the hardwood crowns (Kelty 1986).

- Hemlock can withstand suppression for up to 400 years (Godman and Lancaster 1990).

- Hemlock responds well to release from overstory competition. The release response depends on the active crown size, with smaller crowns in suppressed trees resulting in delayed releases (Anderson *et al.* 1990). Older trees show a better response to release (Marshall 1927). If canopy gaps are less than 5 m wide, hemlock can fill in from lateral crown growth. With a larger gap there is a greater chance of saplings reaching the canopy before lateral growth fills it in (Hibbs 1982).

Hemlock is affected by a variety of damaging agents:

- Heart rot is caused by *Fomes pini* (=*Phellinus pini*), *Polyporus schweinitzii* (=*Phaeolus schweinitzii*), *Polyporus balsameus*, and *Poria subacida*.

- *Armillaria mellea* can damage weakened trees (Fowells 1965; Sinclair *et al.* 1987).

- Hemlock loopers (*Lambdina fiscellaria* and *L. athasaria*) can defoliate trees and cause mortality of weakened trees (Fowells 1965; Rose and Lindquist 1985).

- Hemlock borer (*Melanophila fulvoguttata* (Harris)) attacks weakened trees and can be a problem in blowdown or cut areas.

- A new, serious pest of hemlock is the hemlock wooly adelgid, (*Adelges tsugae* Annand) accidentally introduced to Virginia around 1960. Recent occurrences are reported from Rhode Island and Connecticut. It is dispersed by wind, birds and deer. Logging operations also aid in dispersal, as the larvae can live up to 2 weeks in felled hemlock trees and can be transported on logs to new sites. The insect has survived temperatures of -18° C with low mortality (McClure 1990). The pest has killed thousands of trees in hemlock stands in Connecticut within 2 to 3 years of infestation, and has the potential to cause a major hemlock decline in New England if it spreads further.

- Ungulates have a major effect on hemlock regeneration and have limited recruitment for decades in Algonquin Provincial Park. Numerous studies document the negative effects of white-tailed deer (*Odocoileus virginianus*) (Hough 1965; Anderson and Katz 1993), and more recently, moose (Vasiliauskas 1995) browsing on hemlock seedlings.

- Snowshoe hares (*Lepus americanus*) browse on seedlings, but only accounted for 10 per cent of the damaged seedlings in an Algonquin Park study (Vasiliauskas 1995). Porcupines eat the bark from upper limbs of hemlock and also clip twigs, causing decline and tree mortality.

- Hemlock are sensitive to windthrow, fire damage and sudden changes in stand density from cutting or wind damage causing soil drying (Anderson *et al.* 1990).

- Increasing size and age makes stems vulnerable to shake and radial stress cracks. Leaders are frequently replaced by side branches due to leader death (Hibbs 1981).

3.4.6 Eastern White Cedar

Eastern white cedar is an important commercial species for fencing and posts, lumber, decking, shingles (Johnston 1990; Miller 1990), and as a source of aromatic oils for cosmetic and pharmaceutical products. The species is particularly valuable to white-tailed deer as a source of browse and shelter during severe winters (Verme 1965; Johnson 1975). Cedar is one of three dominant wetland tree species of the Great Lakes-St. Lawrence forest region, along with black spruce and tamarack (Kangas 1989). Important silvical characteristics of white cedar include its shade tolerance, ability to reproduce vegetatively, and quick regeneration following fire (Kangas 1989).

Most cedar stands originate in one of three ways (Pregitzer 1990). High intensity fires burning through cedar swamps during severe drought years leave behind pockets of cedar trees that are able to regenerate the stand through seed. Other cedar stands regenerate through vegetative reproduction. Advanced regeneration through seeding onto decaying logs and stumps, or moss can also perpetuate the stand.

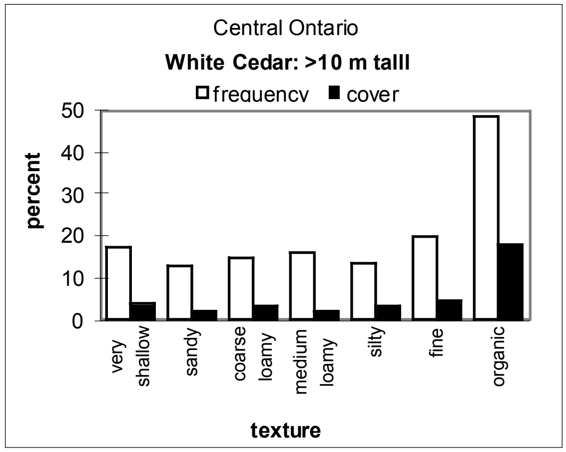
3.4.6.1 Growing conditions for white cedar

Johnston (1990) states that: *Eastern white cedar grows in the Maritime provinces, Anticosti Island, west into southern Quebec, Ontario and the southeast corner of Manitoba. The range extends north in Ontario to the southern portion of James Bay and south into the Lake States, New England, Pennsylvania, with isolated populations farther south in North Carolina and Tennessee. It grows at elevations ranging from sea level to 600 m.*

Cedar grows best in relatively humid climates. Mean annual precipitation ranges from 710 mm to 1170 mm. Mean January temperatures range from -12° C to -4° C, and mean July temperatures range from 16° C to 22° C. The frost-free growing period varies from 90 to 180 days.

Cedar grows on a wide range of organic and mineral soils (FIGURE 3.4.15). It grows best on limestone derived soils that are neutral to slightly alkaline (pH 5.5 to 7.2), moist, and well aerated. It is usually found on cool, moist, nutrient rich organic soils near streams or other waterways. When found on mineral soil, it is associated with seepage areas, limestone uplands or old fields. Most harvesting of cedar occurs in cedar swamps, where the trees are protected from wildfire and outgrow their competitive associates.

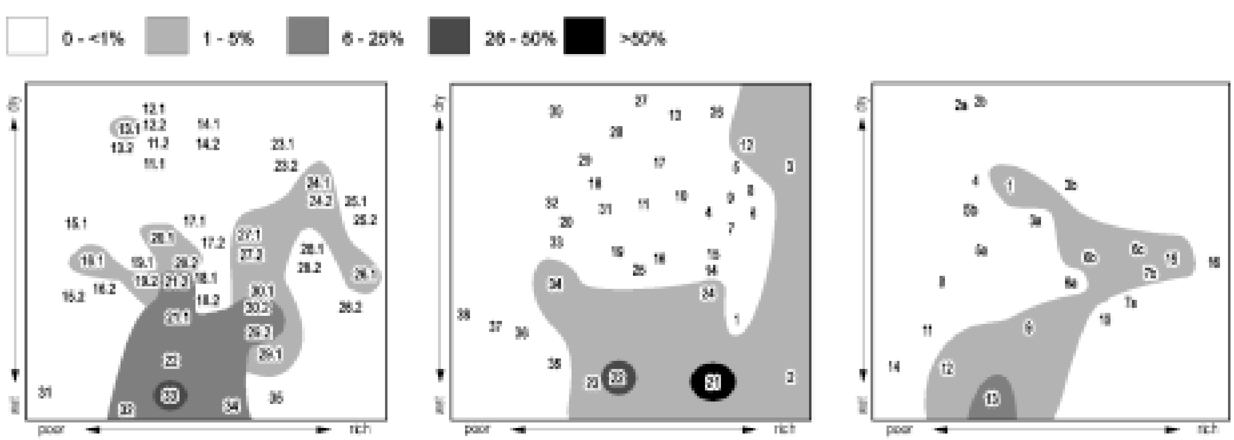
FIGURE 3.4.15: Frequency and cover of white cedar >10 m tall by soil texture based on 1,532 FEC plots sampled in central Ontario. The white (left) outlined bar indicates the percentage of FEC sites within that texture class with white cedar. The black (right) solid bar indicates the per cent cover of white cedar within all plots from that texture class.



3.4.6.2 Ecosites

Cedar is found on a wide range of ecosites in Ontario. In central Ontario it has the highest per cent cover on moist to wet ecosites with moderate to high fertility (***see*** FIGURE 3.4.16a). In northwestern Ontario it is found in vegetation types with similar conditions, but also on rich and dry sites (***see*** FIGURE. 3.4.16b). In northeastern Ontario it has the highest per cent cover on wet sites with moderate fertility (***see*** FIGURE 3.4.16c).

FIGURE 3.4.16: Mean per cent cover of white cedar in the canopy by ecosite and in relation to soil moisture and fertility based on FEC plots sampled in Ontario. The numbers indicate the ecosite type.



a)Central Ontario ecosite types (1,532 FEC plots)

b)Northwestern Ontario Vegetation Types (2,139 FEC plots)

c)Northeastern Ontario ecosite types (1,168 FEC plots)

3.4.6.3 Eastern white cedar seed production

Eastern white cedar is monoecious, with female and male cones usually on separate branches of the same tree. The sexual reproduction cycle takes one year (Johnston 1990). Here is a summary of some of the research on this species:

- Seeds are a light chestnut-brown colour, approximately 6 mm long, and have lateral wings as wide as the seed length. They are mostly wind-dispersed, and travel 45 m to 60 m from the parent tree under normal conditions (Fowells 1965; Miller 1990). Squirrels are also responsible for transporting seeds over longer distances (Miller 1990).

- Good seed crops can occur every 2 to 5 years. Medium to failed seed crops occur at other times. Seed crops can be predicted by red maple seed crops of the previous spring (Godman and Mattson 1976).

- Cones may appear on plants as young as 6 years old; seed production increases significantly by 30 years of age, and is best after 75 years of age (Johnston 1990).

3.4.6.4 Eastern white cedar seed germination and establishment

Observations of eastern white cedar germination characteristics include:

- Cedar seeds have a weak embryo dormancy, and best germination occurs after cold stratification at 2° C to 5° C for 21 to 30 days (Creasey and Myland 1993). Alternately, fall sowing breaks embryo dormancy as the seed overwinters. Seeds stored for long periods, or seed that is dried too fast at high temperatures will require stratification.

- Seeds do not usually last for more than 1 year in the soil seedbank. Therefore, regeneration from the soil seedbank following fire or cut-over is unreliable.

- Cedar will germinate on a variety of moist seedbeds. However, successful germination requires the following physical and environmental characteristics:

    - alternating day/night temperatures of 30° C/20° C respectively (Johnston 1990; Miller 1990)

    - moist seedbeds of rotting logs, stumps, or mosses such as *Heterophyllium*, *Pleurozium*, and *Brotherella* (Holcombe 1976)

    - high soil pH (Pregitzer 1990)

    - blackened soil surfaces from burned organic materials (Pregitzer 1990)

    - to a lesser extent, moist and decaying litter, peat, humus, or *Sphagnum* moss seedbeds

    - partial shade (Schopmeyer 1974).

- Prescribed burning is a useful tool for cedar regeneration (Miller 1990). The benefits of prescribed burning include: 1) reduced slash loading, 2) combustion of un-decomposed mosses, 3) blackening of the seedbed substrate with subsequent increased seedbed temperature, 4) increased soil pH, and 5) reduced hardwood competition.

- Cedar will regenerate by seed on burned uplands (Smith and Borczon 1981; Johnston 1990) or by vegetative reproduction on wet lowlands. Depth-of-burn must be high to expose mineral soil seedbeds on uplands (Johnston 1977; Verme and Johnston 1986). Skid trails with compacted, moist moss also provide suitable germination and establishment substrates for cedar (Fowells 1965).

- Seed germination usually begins in May to June of the year after seeding, and may continue into July and August because of the relatively high temperature required for germination.

Conditions conducive to cedar germination are also conducive to establishment. The following points summarize some observed conditions for establishment of seedlings:

- Constant moisture supply and warm temperatures are critical (Curtis 1959).

- Heavy slash can hinder cedar establishment. Heavy slash cover also provides habitat for snowshoe hares, that browse cedar. A light slash cover, can aid establishment.

- Seedlings grow best on seedbeds that are neutral to slightly acidic (5.5 to 7.2 pH), but will grow on slightly alkaline soil. Older saplings grow better in neutral to slightly acidic soils (Fowells 1965).

- Seedlings do not initially develop the scale-like needles associated with cedar, but possess needle-like seed leaves after germination (Smith and Borczon 1981). Consequently, they can be mistaken for other conifer species, or missed altogether.

3.4.6.5 Eastern white cedar development from seedling to mature tree

Silvicultural prescriptions for cedar must consider the effect of moisture, light intensity, growth, mortality, vegetative reproduction, reaction to competition, and rooting habit to ensure future consumptive and non-consumptive forest uses. The following physical, environmental, and biological factors and conditions can affect the growth and development of cedar from the seedling stage to maturity:

- Difficulty in cedar regeneration does not commonly occur at the germination stage. More common are recruitment problems into older age-classes (Pregitzer 1990). Mortality of established seedlings can be high in naturally regenerated stands. Drought causes mortality, particularly if seedlings are growing on moss, stumps, or hummocks that are prone to drying during the summer. Seedlings can also be smothered by deep *Sphagnum* moss or logging slash (Curtis 1946; Fowells 1965; Jeffers 1976).

- Adequate light and moisture availability are the most important factors for early cedar growth and development. Seedling height growth reaches a maximum at approximately 50 per cent full sunlight, but shoot and root biomass are maximum at full sunlight (Logan 1969). Exposed seedlings tend to have lower survival and growth (Johnston 1990).

- Cedar seedlings grow relatively slowly under both forest and nursery conditions, with an average annual height increment of only 8 cm during the first several years. Shoot and radial growth occur from May until late August or September (Fowells 1965).

- Cedar is shade tolerant, and can withstand suppression for long periods of time. Response to thinning is good at almost any age (Benzie 1963; Fowells 1965). Thinning response increases with site quality. On poorly drained cedar swamps, response to thinning is poor, while on well-drained swamps, response to thinning is favourable (Fowells 1965).

Any parts of cedar stems or branches covered with soil or organic matter and exposed to sufficient moisture can reproduce vegetatively. Curtis (1946) suggests that vegetative reproduction (layering) may be more important than seeding in most swamps because vegetative reproduction is more shade tolerant than seedlings and already has a developed root system. Vegetative reproduction is common in areas with deep organic soils and heavy winter snowfall (Miller 1990).

Root form of cedar seedlings depends on soil moisture holding capacity (Johnston 1990). Seedlings growing in soils with a low moisture holding capacity develop long taproots, while shorter thicker roots with many laterals develop in soils with high moisture holding capacity. On older saplings and trees, shallow, wide-spreading root systems develop. Root grafts are common. Cedar roots form endomycorrhizal symbioses.

Relatively few insect pests or diseases attack eastern white cedar:

- Rare attacks by leaf blight (*Fabrella thujina*) and juniper blight (*Phomopsis juniperovora*) can cause premature browning and shedding of leaf scales and are easily confused with natural browning in the fall.

- Aphids, leaf miners, root weevils, mites, and the cedar tree borer (*Semanotis ligneus*) can occasionally attack eastern white cedar (Pirone 1978).

- Butt-rot fungi attack older trees. These trees subsequently become susceptible to carpenter and red ant colonization (Johnston 1977).

- Cedar leaf miner is a common problem.

- White-tailed deer and moose browse cedar.

- Voles girdle, and white-tailed deer and snowshoe hares (Miller 1990) browse established seedlings (Verme and Johnston 1986).

- Cedar seedlings and trees are susceptible to fire because of their thin, oily, flammable bark and shallow root systems (Johnston 1990; Miller 1990).

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3.4.7 Autecology of Associated Plants

3.4.7 Autecology of Associated Plants

by F. Wayne Bell, William C. Parker, Robert G. White, Dan R. Duckert and Julie A. Elliot

Autecology is the branch of ecology dealing with the study of the responses and adaptations of individual organisms or species to their environment (Lincoln *et al.* 1982). Five literature reviews (Sims *et al.* 1990; Bell 1991; Louter *et al.* 1993; Bentley and Pinto 1994; Bell and Kershaw 1997) and two guides (Buse and Bell 1992; Arnup *et al.* 1994) on the autecology of Ontario's forest plants were published. These publications include information on 8 conifer, 85 deciduous tree and shrub, 27 herb, 17 graminoid, 3 fern, 3 lichen, 3 moss, and 7 sphagnum species found in Ontario.

The species selected for presentation in this section are common trees, shrubs, and herbs found in the forests of Ontario. Common and scientific names are consistent with current names used in Ontario (Newmaster *et al.* 1997) (***see*** TABLE 3.4.1). In each table, species are grouped by life form and then listed alphabetically by scientific name. Their nomenclature, growth habit, reproductive characteristics, phenology and ecophysiology, have been summarized in six 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).

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: 1) life cycle, 2) longevity, and 3) growth pattern. Plants have one of three life cycles (TABLE 3.4.1). Plants may be annuals, biennials, or perennials, and complete their life cycles within 1, 2 and 2+ 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) young tree seedlings. The longevity of perennial plant species can contribute to their competitive status. Long lived species (e.g. white spruce and cedar) generally out compete 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 3.4.1 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.

Plant species with high reproductive capabilities are more difficult to control and easier to promote than species with limited reproductive potential. Almost all plants considered in this section reproduce both vegetatively and sexually (***see*** TABLE 3.4.2 and TABLE 3.4.3). 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 root suckers connected to parent plants with established food reserves and water supply (Zasada 1971) facilitates re-growth 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 (***see*** TABLE 3.4.3). Note that some plants may have more than one reproductive class, however, only the most common on is listed in TABLE 3.4.3. Potential seed production for each species ranges from hundreds to millions of seed 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 that 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 (***see*** TABLE 3.4.4). Seed type and size directly affect seed dispersal. For example, small winged seeds are capable of traveling several kilometers. 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 traveled 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 1997) (***see*** TABLE 3.4.5). 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 years of 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 stresses is useful in planning of forest management activities to favour the growth of crop species (***see*** TABLE 3.4.6).

TABLE 3.4.1: Form, longevity and growth habit of selected species							
	Common Name	Scientific Name	Longevity (years)	Maximum Stem Height (m)	Maximum Area of Clone (m^2)	Zone of rooting	Forms Root Grafts
TREES	balsam fir	*Abies balsamea*	150	25		Org/Min	
	red maple	*Acer rubrum*	150	30		Mineral	yes
	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	
	black spruce	*Picea mariana*	250+	25		Org/Min	yes
	jack pine	*Pinus banksiana*	200+	30		Mineral	
	balsam poplar	*Populus balsamifera*	200	30		Mineral	
	large toothed aspen	*Populus grandidentata*	80-100	18-24 (30)		Mineral	
	trembling aspen	*Populus tremuloides*	120	34	965 000	Mineral	
	mountain ash	*Sorbus* spp.		10		Min/Org	
	American elm	*Ulmus americana*	300	38		Mineral	
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	
	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	
	velvet leaf blueberry	*Vaccinium myrtilloides*		0.5	300+	Org/Min	
	viburnum	*Viburnum* spp.		2		Mineral	
	large leaf aster	*Aster macrophyllus*		1		Mineral	
H	blue joint grass	*Calamagrostis canadensis*		1-2		Min/Org	
E	sedges	*Carex* spp.		1		Min/Org	
R	field bindweed	*Convolvulus arvensis*				Mineral	
B	fireweed	*Epilobium angustifolium*	20+	2		Mineral	
S	grasses	Poaecae		1		Min/Org	
	bracken fern	*Pteridium aquilinum*	100	1-2		Org/Min	no

TABLE 3.4.2: Asexual reproduction methods of selected species

		Root Origin *		Shoot Origin		
	Common Name	Root Suckers	Rhizomes	Root Collar Sprouts	Lower Stem Sprouts	Layering (stolons)
	balsam fir	nil	nil	nil	nil	secondary
	red maple	nil	nil	primary	secondary	secondary
	white birch	nil	nil	primary	secondary	nil
	black ash	secondary		primary		
T	larch	nil	nil			primary (in north)
R	black spruce	nil	nil	nil	nil	primary
E	jack pine	nil	nil	nil	nil	nil
E	balsam poplar	primary	nil	secondary	secondary	nil
S	large toothed aspen	primary		secondary	secondary	
	trembling aspen	primary	nil	secondary	secondary	nil
	mountain ash	nil	nil	secondary	unknown	nil
	American elm	nil	nil	primary		nil
	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
S	sweetfern	nil	primary	secondary	secondary	nil
H	red osier dogwood	secondary	nil	secondary	secondary	primary
R	beaked hazel	primary	nil	secondary	secondary	secondary
U	bush honeysuckle	nil	primary	unknown	secondary	nil
U	sheep laurel	nil	primary	unknown	secondary	secondary
B	bog laurel	nil	primary	unknown	secondary	secondary
S	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
	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
	velvet leaf blueberry	nil	primary	secondary	secondary	nil
	viburnum	nil	secondary	primary	unknown	secondary
HERBS	large leaf 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 uses corms as a secondary method of asexual reproduction

TABLE 3.4.3: Sexual reproduction methods of selected species						
	Common Name	Reproduction Class	Propagule Fruit Type	Minimum Seed Bearing Age (years)	Periodicity of Large Seed Crops (years)	Seedling Regeneration Strategy[1]
TREES	balsam fir	Monoecious	cone	10-15	2-4	SB
	red maple	Dioecious	samara	4	annually	SB
	white birch	Monoecious	catkin	15	2	CSC
	black ash	Perfect	samara		3-4	SSB
	larch	Monoecious	cone	4-15	3-6	CSC
	black spruce	Monoecious	cone	10-15	1-4	SC
	jack pine	Monoecious	cone	3-15	3-4	SC
	balsam poplar	Dioecious	catkin	8-10	annually	CSC
	large toothed aspen	Dioecious	catkin	10	2-3	CSC
	trembling aspen	Dioecious	catkin	10-20	4-5	CSC
	mountain ash	Perfect	pome	15	annually	CSC
	American elm	Perfect	samara	15	annually	CSC
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	SSB
	currants	Perfect	berry	3-5	2-3	SSB
	wild prickly rose	Perfect	hip	2	1-2	SSB
	wild raspberry	Perfect	drupe	2	annually	SSB
	willows	Dioecious	catkin	2-4		CSC
	red elderberry	Perfect	drupe		annually	SSB
	low sweet blueberry	Perfect	berry	4		
	velvet leaf blueberry	Perfect	berry			
	viburnum	Perfect	drupe	3-5	annually	SSB
	large leaf aster	Perfect	berry		annually	CSC
H	blue joint grass	Perfect	caryopsis		annually	CSC
E	sedges	Perfect/Imperfect	achene	1		SSB
R	field bindweed	Perfect	capsule		annually	SSB
B	fireweed	Perfect	capsule	1	annually	CSC
S	grasses	Perfect/Monoecious/ Dioecious	caryopsis	1	annually	SSB
	bracken fern		sporangium	2		

1/ SB = seedling bank; SSB = soil seed bank; CSC = current seed crop; SC = serotinous cones. The dominant sexual reproduction strategy is listed.

TABLE 3.4.4: Seed dispersal characteristics of selected species

	Common Name	Seed Type	Average Cleaned Seeds/kg	Time of Seed Ripening	Dispersal 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
	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.
	black spruce	winged seed	1,258,400	Aug.-Sept.	200 m	wind, mammals	Sept.-Apr.
	jack pine	winged seed	288,200	September	40-60 m	wind, mammals	all year
	balsam poplar	seed		June-July	several km	wind, water	late June-July
	large toothed aspen	seed	5,600,000	June	several km	wind	June
	trembling aspen	seed	5,600,000	June	several km	wind	June
	mountain ash	seed	352,423	Aug.-Sept.		birds, mammals	Aug.-Mar.
	American elm	samara	156,000	May	90-400 m	wind, water	June
SHRUBS	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
	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
	velvet leaf blueberry	seed		July-Aug.		birds, mammals	August
	viburnum	stone	30,464	July-Sept.		birds, mammals	Spring
	large leaf aster	seed		September		wind	
H	blue joint grass	grain	7,346,687	Aug.-Sept.		wind	Aug.-Sept.
E	sedges	achene		July-Sept.		wind	Aug.-Sept.
R	field bindweed	achene				wind	
B	fireweed	plumed seed		Aug.-Sept.	10-300 km	wind	
S	grasses	grain		July-Sept.		wind	Aug.-Sept.
	bracken fern	spore				wind, water	

TABLE 3.4.5: Seed germination characteristics of selected tree species								
					Germination Temperature (°C)[4]			
Species	Viable Seeds per Kg	Dormancy[1]	Cold Stratification Period[2]	Per cent Germination[3]	Low	Optimal	High	Preferred Seedbed[5]
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
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
black spruce	888,000	None, C	14-21	60-90	7	12-28	34	MS, SM, PM, BO, BD
jack pine	273,000	None, C	14	70-85		16-27		MS, BD
balsam poplar[7]		None	0	> 90	5	10-40	45	MS
large-toothed aspen	4,200,000	None	0	> 80	5	10-29	35	MS
trembling aspen	4,200,000	None	0	> 75		2-30	35	MS, H
mountain ash[8]	65,000	C	90-120	15-20		20-30		
American elm	47,000	None	None	10-60		10-30		MS, DW, H

[1] Dormancy refers to a state that prevents germination under environmental conditions favourable 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 per cent germination. For those species sometimes lacking dormancy, a stratification period is identified, and may be higher during years of heavy seed crops.

[3] Per cent 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 per cent germination of non-dormant, fully imbibed seed is markedly reduced (LOW), optimal for germination, or above which per cent 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 the embryo to mature prior to stratification.

[7] Seed viability (i.e. per cent 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 per cent of oven dry weight are optimal for germination of the species listed. This target moisture content can be achieved by soaking seeds in aerated water for 24 to 48 hours.

TABLE 3.4.6: Environmental requirements and adaptation to environmental stresses

Species	Environmental Requirements*			Tolerance or Adaptation 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
white birch	M	M	Very Intolerant	5.0-7.0	M	L	L	L	M
black ash		M	Intermediate	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
black spruce	L-M	L	Intermed.-Tol.	5.0-7.0	L-M	M	M		L-M
jack pine	L	L	Very Intolerant	4.5-7.0	H	L	M		M-H
balsam poplar	M-H	M-H	Very Intolerant	Acid Intolerant	L	M	L		
large-toothed 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
mountain ash	L-M	M	Intolerant	4.5-5.5	M	L	L		
American elm	L-M	M	Intermediate	5.5-8.0	M	M-H	L-M		M

1/ Range in soil pH in which good 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 watertable 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

3.4.7.1 Summary

With the focus on emulating natural disturbances and development of ecologically sustainable forest practices, 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.

Species' response to disturbance is not a single ecological characteristic, but the collective strategies of a plant species to evade, escape, or resist disturbance (Grime 1977). 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. overstory removal, prescribed fire, mechanical site preparation, cutting, and herbicides).

Information on the autecology and physiology of 46 plant species occurring in the Great Lakes-St. Lawrence conifer forest of Ontario collected from a number of sources are presented in six tables for use in forest management decision making processes. Species presented in these tables are grouped by lifeform and listed alphabetically by their scientific name. These tables present important autecological characteristics needed to understand how common forest trees, shrubs and other plants will respond to disturbances.

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3.4.8 Damaging Agents

3.4.8 Damaging Agents

by J. Steve Munro and Joe Churcher

Insects and diseases that are native to a particular area play an integral role in any forest ecosystem. For example, insects are part of the food chain and, both insects and pathogens accelerate the rate of decay of organic matter on the forest floor. They may also play a role in removing older, less vigorous trees to make way for younger, more robust ones.

Not all insects and diseases found in a forest, however, are native. Some have been introduced to the area, often accidentally and often without the natural controlling agents that normally keep the organism in balance in their home range. Similarly, native insect and disease populations may escape their natural controls, temporarily growing to epidemic proportions and having more of an impact on the forest than they normally would.

When an introduced organism or a native organism at an epidemic level begins to threaten the long-term health of the forest or some more immediate value of the forest, it is viewed as a “pest”. It is in these situations that the forest manager may wish to protect the forest through the use of some form of pest management technique e.g. through the use of preventative silvicultural treatments or directly through the application of a biological or chemical pesticide.

Some silvicultural practices can be used to prevent or minimize the impact of pest organisms. For instance, the shelterwood silvicultural system can be used to provide suitable habitat for predators of the white pine weevil, decreasing the probability of epidemic populations of this insect in white pine stands. In other cases, some management practices may actually accentuate the effects and spread of some pests e.g. harvest and mechanical site preparation can cause breakage and wounds to trees creating entry courts for wood decay fungi.

Insects and disease are not the only natural agents in a forest ecosystem which may damage trees. Other examples of damaging agents include wildlife, wind, drought and frost. They are often beyond the direct control of the forest manager. However, a forest manager may use information on the adaptations of crop and non-crop plants to prevent excessive damage. For example, frost damage to planted white spruce may be reduced by not planting in known frost pockets and hemlock and cedar browsing by ungulates may be reduced by creating habitat conditions that are not preferred by deer and moose.

Reference Tables

The following table will provide a quick reference and review of common pests.

A large volume of literature and reference material is available to forest managers about insect and disease biology and management. The recommended reading section below lists some of these.

Due to changing pesticide regulations, refer to the Ontario Pesticides Act for current legislation, licensing information and a current list of approved pesticides. For application rates and methods, refer to product labels.

Silvicultural management options such as controlling overhead shade or crown closure can be effective in controlling some pests. For example, tree markers can mark the forest to a target crown closure to reduce white pine weevil damage. Tree markers can also assess and mark for removal, trees containing white pine blister rust or red ring rot.

Recommended Reading

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3.4.8.1 **White pine weevil** *Pissodes strobi* (Peck)				
HIGH RISK SITES	**AFFECTED SPECIES**	**BIOLOGY, SIGNS, AND SYMPTOMS**	**RANGE**	**MANAGEMENT IMPLICATIONS**
Unshaded conditions with few cavity trees and low levels of coarse woody debris, and with low relative humidity and high air temperature. Dry sites, are ideal for overwintering of the adults.	White pine trees between 2 to 6 m in height are most susceptible. Also, jack pine and Norway spruce are particularly susceptible in Ontario.	The white pine weevil is a native species, and exists today together with its predators and parasites. Behaviour and development of the insect is largely influenced by microclimate, including bark temperature, solar radiation, and atmospheric moisture. Insects prefer a thick stem leader, usually rejecting leaders less than 4 mm in diameter. Adults reside in litter close to the bole, emerging over several weeks in early spring. Adult weevils are poor flyers; they have difficulty reaching heights in excess of 6 m. Feeding and oviposition are rapid and are largely confined to the bark of preceding year's growth; the leader is effectively girdled. Leader withers, assuming characteristics of a shepherd's crook. Adults emerge from the stem in summer or early fall, seeking hibernation sites.	Throughout the ecological range of white pine.	Without management there is potential for reduction in stem quality and value by 20 to 60 % (less for short logs) based on current utilization standards. Besides stem deformation, stem stubs resulting from insect damage are primary pathways for disease infection.

SILVICULTURAL CONTROL(S)

Natural controls

According to Rose and Lindquist (1973), natural controlling agents alone are unable to limit weevil damage to tolerable levels in plantations. However, natural enemies should be an important component of an integrated weevil management strategy. The effectiveness of natural enemies could be enhanced by using the following techniques which are discussed in more detail in Szuba and Pinto (1991) and summarized here.

Maintain overhead shade (approximately 50 % crown closure) to provide optimal conditions for predator and parasite populations in host species with a tolerance for shade. Retention of cavity trees and maintenance of coarse woody debris is important in providing habitat for predators of weevil. Open planting of white pine should be avoided on dry sandy soils, because height growth is comparatively slow and stocking is difficult to control. The prevailing microclimate on these sites is often dry, and protection from associated vegetation is minimal. These conditions are optimal for weevil development. On these sites, white pine may be planted under the protection of an established nurse crop (e.g. jack pine, larch, or poplar).

Alternately, white pine may be introduced in the next rotation under a partial canopy of the forest crop. On fresh to moderately moist soils, height growth is more rapid and crown closure occurs sooner. Stocking levels are easier to control, provided that competing vegetation is controlled.

The clipping and burning of leaders damaged by the weevil is appropriate in open-grown plantations. This treatment should be applied before adults emerge. Leaders may be stored on-site in mesh covered drums allowing natural predators and parasite populations to increase. The mesh should be of a size as to not allow weevils to escape.

Where a reduction in population levels is expected, clipping must be carried out over the entire area to prevent re-infection from surrounding reservoir areas. Clipping can often be carried out at the same time as manual cleaning operations with minimal additional cost.

Establish high density plantations as the first 20-30 years of growth in a plantation are critical for the production of straight stems (deGroot 1985). Steill (1985) advocates protection of adequate numbers of white pine from weevils until they reach 1 log length in height (5 m).

Chickadees (*Parus* spp.) and downy woodpeckers (*Picoides pubescens*) are probably the primary vertebrate predators of immature weevils. Populations of these cavity-nesters may be limited by availability of snags. Optimal habitat for these species could be provided by retaining at least 6 soft snags/ha > 15 cm dbh in young stands (Evans and Conner 1979; see also James 1983).

Downed woody material (logs > 10 cm in diameter) is an important component of habitat used by small mammals which prey on adult weevils hibernating in the duff. The availability of woody debris can be enhanced by leaving tops in the bush and by avoiding windrowing of large slash.

Chemical Control

Spray operations must be timed to coincide with:

(1) emergence of hibernating adults in spring before egg-laying, or (2) emergence of new adults in August before they enter winter hibernation (deGroot 1985, McGalliard and Houseweart 1985, Lavalle and Benoit 1989). Unfortunately, emergence covers a long time-span in both seasons and the persistence of most registered chemicals is short (e.g., 2-3 weeks for methoxychlor with ground spray equipment (deGroot 1985). Thus, repeat applications of contact insecticides are often necessary.

Aerial sprays have not been widely used to control white pine weevil infestation in Ontario, and no large scale spray operations have been conducted in recent years. Ground spraying is done to control white pine weevil*. (Taylor Scarr, personal communication, FMB, Sault Ste. Marie, ON.)*

3.4.8.2 Red-headed pine sawfly *Neodiprion lecontei* (Fitch) **and European pine sawfly** *Neodiprion sertifer* (Geoffroy)

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Open white and red pine stands on shallow or disturbed soil, especially adjacent to a hardwood edge. Stands less than 5 m tall.	Red pine and, to a lesser extent, white pine.	Red-headed pine sawfly larvae feed in gregarious colonies and are active from mid-summer to fall, depending on weather conditions. In heavy infestations, preference is shown for the previous year's needles. European pine sawfly larvae are gregarious. Insects are active in the spring with timing dependent on weather conditions. Larvae feed only on the foliage of the previous year's shoots.	Infestations largely confined to an area south of the Mattawa and French rivers in Ontario as well as along the Lake Huron north shore.	Can cause growth losses or mortality in young stands.

SILVICULTURAL CONTROL(S)

Use a systemic or contact insecticide when the larvae are feeding. A nuclear polyhedrosis virus (NPV) can be used as a biological control. Contact the local OMNR area forester for further information.

3.4.8.3 Hemlock looper *Lanbdina fiscellaria fiscellaria* Guenée

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Mature stands of principle host trees.	Hemlock, cedar and balsam fir.	Overwintering eggs hatch in late May or June, and young larvae feed on new foliage. Larger larvae will feed on the old needles. Damaged needles turn brown.	Throughout the range in Southern Ontario, including Manitoulin Island.	Tree mortality is restricted to mature stands, however infestations usually persist for only a few years. Damage on balsam fir is more severe if hemlock looper infestations immediately follow a spruce budworm outbreak.

SILVICULTURAL CONTROL(S)

Natural controls Natural predators, parasites, disease, starvation and weather reduce numbers following an infestation.

Chemical controls To reduce damage in infected areas, use an approved contact or stomach insecticide at the caterpillar stage.

3.4.8.4 Cedar leaf miner *Argyresthia thuiella* (Packard)

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Mainly in southern Ontario	Cedar	Mining occurs in the spring, and causes discoloured foliage. Severe mining of foliage often causes twig, branch or tree kill. However, severely injured trees will often produce new foliage later on in the growing season	Southern Ontario	Minimal for natural forest trees, most often ornamental trees are affected.

SILVICULTURAL CONTROL(S)

Natural control On individual trees prune and destroy affected twigs in the spring.

Chemical Control Apply an approved systemic insecticide in the spring.

3.4.8.5 White pine blister rust *Cronartium ribicola* J.C. Fisch.

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Areas that are favourable to dew formation such as valleys, lower slopes, north-facing slopes and adjacent to open water.	White pine.	A non-native fungus, it enters through needles and attacks living bark and cambium, first breaking out in blisters and later forming pustules. Spores transmit the disease to gooseberry or currant plants. Spores from these hosts in turn infect healthy trees.	Throughout the commercial range of white pine.	Can cause heavy mortality and loss of tree vigour in young, developing stands.

SILVICULTURAL CONTROL(S)

Reduce abundance of the alternate hosts (gooseberry and currant) of blister rust. These plants are not shade tolerant, so their abundance and vigour can be reduced by maintaining a closed canopy. Control lower vegetation in stand openings. Avoid establishment of white pine in open-grown plantations on dry sites where stocking is difficult to control. Schedule early pruning of the lower branches of all white pine less than two metres in height in plantations or stands growing on moderate to high risk sites. Blister rust infection can be reduced by removing the lower one third of the crown in very young stands (Van Arsdel 1964; OMNR 1987).

3.4.8.6 Scleroderris canker *Gremmeniella abietina* (Lagerb.) M. Morelet.				
HIGH RISK SITES	**AFFECTED SPECIES**	**BIOLOGY, SIGNS, AND SYMPTOMS**	**RANGE**	**MANAGEMENT IMPLICATIONS**
Both strains: Trees in depressions and frost pockets, where a cool, moist microclimate may develop, are most susceptible.	*North American strain:* Red pine and occasionally white pine. Affects smaller trees. *European strain:* Affects all tree sizes.	Fungus produces two types of spores, with spore production and colonization of host tissue occurring where weather is cool and moist. Conidia, often spread by rain splash, are considered the main source for local intensification of the disease. Ascospores have a role in local spread and are the main inoculum type for long range movement. Spread within the host occurs mostly during fall and winter. An orange discolouration appears at the base of new needles, most often in early summer. Needles turn brown and fall off the branch, leaving a bare dead shoot. An abundance of dead shoots provides cause to suspect damage is the result of scleroderris infection. Cankers may develop on branches or stem with potential to girdle and kill the tree. Green to yellow-green stain may appear underneath the bark in infected regions. *European strain* has the same signs and symptoms as the North American strain, but is more aggressive, infecting trees of all sizes. Infection usually starts in upper crown.	*North American strain*: Throughout the commercial range of red pine with the exception of the eastern and south-western portions of Ontario. *European strain:* Several infection sites discovered in OMNR Districts of Bancroft and Parry Sound. Potential to develop anywhere across red pine's commercial range.	*North American strain*: Can cause mortality of current year's shoot and loss of tree vigour in stands where trees are less than 2 m in height. Occasionally causes tree mortality in very young stands. *European strain*: Shoot infection. Loss of vigour and mortality of small and large trees.

SILVICULTURAL CONTROL(S)

The risk of infection and spread of this disease can be substantially reduced by not establishing red pine in depressions or frost pockets. This is a very important consideration when selecting sites for planting red pine. Monitoring stands for scleroderris must be an integral component of all condition assessments scheduled after planting. Immature stands should be thinned so that stand and individual tree vigour are maintained.

N*orth American strain*: Where an infection hazard is known to exist, inspect all new plantings in May and June. The needle -base-browning symptom is apparent at this time. Rogue out all infected trees, and either burn or remove them from the site. Where a small number of trees are infected, remove infected trees or branches. Lower branches should be pruned several times before trees reach two metres in height. Often, infection remains low until crown closure begins. Very close initial spacing is undesirable, since trees cannot outgrow the disease at this stage. Crown closure may occur prior to trees reaching two metres in height where initial spacing is very close.

Where the *European strain* of the causal fungus is suspected, it should be reported to the Forest Health Unit of the Canadian Forestry Service (CFS). CFS personnel are trained in processing quarantined material. This quarantine procedure helps to ensure that infections are confined locally. Race identification requires lab facilities, and CFS handling ensures good sample material. When presence of the European strain is confirmed, the recommended strategy is on-site destruction of infected materials. Burning of infected trees or tree parts is necessary. The remaining stand should be thinned in order to maintain stand and individual tree vigour.

3.4.8.7 Fomes root rot *Heterobasidion annosum* (Fr.:Fr.) Bref.

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
All sites in southern Ontario	Red and white pine. Potential for development in recently thinned stands	Spores germinate on fresh stumps in thinned stands and colonize stump and root tissues. The pathogen spreads out from single tree infection centres through root grafts, causing gradual decline and mortality of trees. When root systems have partially decayed, a fruiting body is produced at, or slightly below, the ground line at the base of the tree. Fresh cut stumps are susceptible to invasion for 10-14 days.	Confined to Southern Ontario. Insignificant in northern Ontario.	Potential for vigour loss and mortality in infected stands.

SILVICULTURAL CONTROL(S)

Red pine is very susceptible to infection by fomes root rot. Primary infections can be controlled by chemically treating all cut stumps with dry granular borax. This treatment provides an effective barrier against infection as the disease spreads to neighbouring trees by way of root grafts.

Secondary infection can be limited by removing pockets of dead and dying trees associated with known infection centres and by removing all living trees within 20 m of the outer perimeter of these pockets. This action should buffer the remaining trees from infection with a wall of dead roots. All cut stumps should be treated with borax when using this method.

3.4.8.8 Red ring rot *Phellinus pini*

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Usually shallow soils with restricted rooting	White pine and to a lesser extent, red pine. Decay is prevalent in the butt region of the tree. Decay is very significant in overmature stands.	Pathogen enters the trunk through external wounds (logging scars, root injuries, or weevil- affected branch stubs). Fungus causes distinctive white pocket rot, the pockets being surrounded by relatively firm wood tissue	Throughout the range of the host trees.	Will affect optimum rotation age. Can cause very significant growth and value losses, especially in overmature stands.

SILVICULTURAL CONTROL(S)

Losses to red ring rot in immature stands can be minimized by avoiding unnecessary damage to the residual stand during harvest operations (*see* Section 9.0 "Harvesting Considerations"). Harvest damage includes scarring of boles and damage to the root systems, which can provide entry points for decay fungi, including red ring rot. Overmature stands should be harvested before losses become significant.

3.4.8.9 White-tailed deer				
HIGH RISK SITES	**AFFECTED SPECIES**	**BIOLOGY, SIGNS, AND SYMPTOMS**	**RANGE**	**MANAGEMENT IMPLICATIONS**
Where alternate preferred browse is scarce. Deer yarding areas.	Hemlock, cedar and white pine. Small seedlings and occasionally, lower branches of taller trees.	Terminal shoots and branches are consumed, causing forked stems, growth loss, and seedling mortality.	Throughout the range of deer.	Could be a concern in areas of high deer densities where other preferred browse within reach of the animals is lacking. Could be a concern in some shelterwood cuts if sufficient browse is unavailable. Where deer populations are high, they are the limiting factor in yellow birch regeneration.
SILVICULTURAL CONTROL(S) Damage caused by deer can be minimized by providing sufficient browse to support desired population levels within the forested area. Maintain deer herds at or below winter carrying capacity				

3.4.8.10 Mice and voles

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Damage potential is highest where soils are nutrient rich, with a fresh to moist moisture regime. Grass and herb vegetation provide cover and security for rodents	Both pines. Affected trees are less than 1 m tall.	Bark is gnawed at base of trees; girdling may result, with needles turning brown. Mouse and vole populations fluctuate	Throughout the commercial range of white and red pine.	Mice and voles can cause extensive damage and mortality where competing deciduous vegetation is abundant.

SILVICULTURAL CONTROL(S)

Damage can be minimized by controlling grass and herbaceous vegetation which provides food and shelter.

3.4.8.11 Rabbits and hares

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Damage is greatest in clearcuts, because of potential for the development of good habitat such as slash piles, dense hardwoods, and shrubs. Open fields where there is dense cover of hardwoods or shrubs in adjacent areas.	Both pines, but especially white pine. Damage usually confined to trees less than 1 m tall. Norway spruce and jack pine preferred over white and red pine.	Affect terminal shoots and branches, causing forking of stem, growth loss, and seedling mortality.	Throughout commercial range.	Can cause extensive clipping and defoliation of young developing pine

SILVICULTURAL CONTROL(S)

Damage by rabbits and hares can be limited by disposing of slash piles and controlling vegetation in site preparation and tending operations.

3.4.8.12 Porcupines

HIGH RISK SITES	AFFECTED SPECIES	BIOLOGY, SIGNS, AND SYMPTOMS	RANGE	MANAGEMENT IMPLICATIONS
Stands in proximity to Scots pine plantations	Red pine, Scots pine and to a lesser extent, white pine.	Girdle branches and kills tops of trees.	Throughout commercial range.	Can seriously affect quality of individual trees.

SILVICULTURAL CONTROL(S)

Create habitat for natural predators such as fisher to help control populations.

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4.0 Quality Development in Trees

4.0 Quality Development in Trees

by Jeff Leavey

People conducting silvicultural treatments must not only recognize quality in the standing tree, but also understand how these characteristics may be maintained, or improved over time. Recognition and evaluation of both current and potential tree vigor, risk, and quality are important elements in successfully applying tending and even-aged systems which require crop tree identification and release.

Little information on changes to Great Lakes-St. Lawrence conifers is currently available. Most literature describes information related to changes in the quality of tolerant hardwood trees. Relevant information from this limited source has been used in this section.

4.1 Assessing Individual Tree Vigor Potential

Residual trees in shelterwood or clearcut with seed tree systems must be: 1) of high genetic quality, 2) able to produce high volume, and 3) able to produce viable seed for regenerating the next stand. Other trees of less desirable quality may also be left for a variety of reasons including: 1) providing crown closure to reduce the invasion of intolerant species, 2) helping to prevent seedbed desiccation, 3) reducing risk of attack by white pine weevil, and 4) helping to achieve social or wildlife habitat objectives.

Vigor potential may be defined as *the relative capacity of a tree to increase in size* (mainly in diameter and volume). Assessing relative tree vigor when choosing residual stems should be based on the following features (Smith 1954; Hamilton 1969):

- **Crown position**: Classifying trees by position of their crowns in relation to forest canopy (i.e. dominant, codominant, intermediate, and over-topped or suppressed) provides an indication of the amount of direct sunlight received, which in turn influences photosynthetic rate.

- **Crown size**: Size of the crown (length, width, and volume) is an index of surface area available to trap light energy for photosynthesis and thus is an indicator of the amount of carbohydrates manufactured for use in growth. Crown area is also important for cone and seed production. Crown dimension and space requirements for adequate growth vary with species and are outlined (primarily for tolerant hardwoods) by Arbogast (1957), Smalley (1975), and Marquis *et al.* (1984) for crown diameter; and by Gevorkiantz (1956), Ward (1964), Lorimer (1983) and OMNR (1983) for live crown ratio (LCR).

- **Crown quality**: Regardless of size and position, the crown must be healthy to perform its function well. Chlorosis, sparse needles, dead twigs, coarse branches (relative to the species), and flat-topped shape indicate low vigor (OMNR 1983).

- **Bark character**: Tree vigor can be determined by examining bark firmness and the nature of its fissures and ridges. Examples of the technique (mainly dealing with tolerant hardwoods) are outlined in OMNR (1983), Arbogast (1957), Burkle and Guttenburg (1952), Sajdak (1967) and Clausen and Godman (1969).

- **Degree of competition**: Stocking density of competing neighbours affects the current growth rate of potential crop trees. Removal of competition provides opportunities for growth acceleration and improvement of quality, depending on the state of the factors just discussed and silvical characteristics of the species.

- **Stand relationships**: Consideration of individual tree vigor must be kept within the perspective of overall management objectives for stand density, structure, and species composition (***see*** Section 5.0 "Stand Growth and Yield").

4.2 Assessing Individual Tree Risk Potential

To have value potential, residual trees must survive and grow at least until the next cut. High risk trees are those that may either die or deteriorate significantly in quality due to rot development, windthrow, or breakage during the period. Such trees are usually removed from the stand in early harvest operations or improvement cuttings. However, in high-graded stands with low residual quality and/or stocking, average quality may be such that some modest-quality or low-quality trees may have to be retained to achieve residual shade/light targets (vegetation management objectives). Even high-value, vigorous trees may be of high risk, and therefore of low potential, because of crown damage or excessive lean (OMNR 1990).

4.3 Assessing Individual Tree Quality Potential

There is a fundamentally different philosophy involved in grading hardwood and softwood trees and their products (OMNR 1990). For hardwoods, species and grade are more important for determining value of lumber than volume. Quality hardwood lumber is used for furniture and cabinetry work and is graded for appearance, while softwoods, often used for construction, are usually graded for strength (Kasile 1982). The basis of hardwood lumber grading is the number of clear cuttings that can be taken from a board; for softwoods, it is the number and type of defects within a board, and how they affect strength.

From a general point of view, product quality varies with the following factors in Ontario:

- **Tree DBH**: Value per tree increases with increasing diameter because of correspondingly larger "quality-zone" component in the logs, which yields a greater percentage of high-value lumber grades such as selects, and better (Petro 1962).

- **Site region**: Morawski (1971) found the percentage of "selects and better" lumber grades sawn from grade 1 logs was 30.4 per cent in Site Region 5E compared to 49.3 per cent in Site Region 6E.

- **Cull factor**: The overall extent of defect varies with site region, land type, and species.

- **Tree growth rate**: Potential quality is limited by type of defect that occurs in a tree.

The future growth rate, however, will greatly influence the rate of value development, since quality of defective trees may improve if their growth rate is sufficiently accelerated.

Estimates of cull or quality can be further refined by using tree classifications that recognize defect indicators and log quality and volume in a standing tree.

4.4 Growing Stock Classification Systems

From a tree-marking or stand assessment point of view, it is important to be able to recognize quality potential as the ability of the selected tree to not only increase in diameter and hence value, but to contribute towards regenerating the next stand. Generally, selected residual crop trees are already the best quality trees.

The term "crop tree" is applied to acceptable growing stock to be retained for use in maintaining appropriate sunlight/shade relationships, and for providing seed. They are essentially the "better quality stems in any stand". A crop tree selected in one location may be of much lower quality than a crop tree selected in another location. However, they are the best to be found and are selected for retention, some of which will be carried through to final harvest cut at rotation age.

A crop tree would ideally have most of the following characteristics:

Crown
- dominant or co-dominant
- dense, fine branching with few large openings
- disease free - no evidence of blister rust, no yellowing of needles
- 35 to 55% live crown ratio (LCR).

Stem
- single-stemmed, straight
- high forks permitted where risk to breakage is low
- bole free of dead branch stubs for the first two logs (10 m / 34 ft).

Bark
- thrifty, vigorous, (i.e. tight bark *vs*. platy flakes of over-mature trees)
- no evidence of red rot.

Butt
- no excessive butt flare which indicates internal defect.

Quality, or value, of trees may be estimated by different methods depending upon the purpose and/or stage at which the estimate is conducted. Although estimation of volumes is often a critical element of harvesting, further prediction of value over time is also required. Growing stock classifications are assigned to trees to indicate their potential for development. They are not product-specific and may be applied to trees before they reach merchantable size. Once trees reach merchantable size, tree grading rules may be applied to estimate log or lumber grade yields. After trees are harvested, log grade rules are applied to estimate lumber recovery from logs.

Few tree classification systems have been developed and published in Ontario which relate potential of individual white and red pine trees for their economic value and available or potential product volumes. Generally, the majority of classification systems for white and red pine to relate growing stock and grade are derived from acceptable and unacceptable growing stock principles.

- **Acceptable Growing Stock (AGS)**: Trees that exhibit such form and appearance of good vigor that can reasonably be expected to maintain and/or improve their present quality for the next 20 year period. Trees will be (visually at least) free of interior defect.

- **Unacceptable Growing Stock (UGS)**: Trees are of high risk or of such poor quality that they cannot reasonably be expected to maintain present quality for next 20-year period.

The accuracy of growing stock and volume estimates is improved upon division into additional classes (***see*** TABLE 4.0.1).

TABLE 4.0.1: Two class tree classification system for pine

TWO CLASS SYSTEM	
Acceptable Growing Stock	Unacceptable Growing Stock
Crop trees exhibiting good vigor that will maintain present quality for next 20 year period. Trees will be visually free of interior defect.	Poor quality trees that cannot reasonably be expected to improve or maintain their present quality for the next 20 year period.

A well conceived tree classification system for use in tree-marking will allow markers to maintain growth standards by retaining trees with high growth potential, thus providing growing stock to increase in value and provide optimum volume and quality seed for establishing the new stand. Information on tree classification systems is available *in A Silvicultural Guide For The Tolerant Hardwoods Working Group in Ontario* (OMNR 1990).

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5.0 Stand Grwoth and Yield

5.0 Stand Growth and Yield

by Murray E. Woods, James A. Rice and Eric Boysen

Growth and yield tools are fundamental to managing forests in a sustainable manner. Many tools have been developed to estimate individual tree growth. Tools that predict growth rates and yield estimates are also available for stand level prescriptions. With these tools, forest managers can examine the probable effects of various silvicultural decisions (e.g. cutting intensity, harvest scheduling) on the long-term sustainability of the forest resource.

While the trend in growth and yield studies is the development of powerful computer-based growth models, other traditional tools (alone or in combination) can be used to evaluate management alternatives in prescription development and forest planning. Foresters regularly use 1) site class and site index curves, 2) standard, local and form-class volume tables, 3) normal yield tables and yield curves, and 4) density management diagrams and stocking guides, and 5) cull tables. The application and relationship of each of these tools is shown in FIGURE 5.0.1.

A complete set of Ontario-derived growth and yield tools are not available for all species in this silvicultural guide. However, growth and yield models from adjacent provinces and states are used in this guide for species that lack Ontario models. Research will continue in both the development and standardization of these tools for Ontario. ***A validation of the tools provided from other agencies (provinces and states) should be carried out in local areas before they are adopted.*** A summary of the tools currently available for each species is presented in TABLE 5.0.1.

This section describes the development of growth and yield tools, where they can and should be used, and more importantly, their limitations. This section includes:

- a description of applicable growth and yield tools
- an explanation of how each tool can be used in stand-level management
- fact sheets of selected growth and yield tools by species, and
- procedures for using some of the management decision tools.

FIGURE 5.0.1: Growth and yield prediction pathways

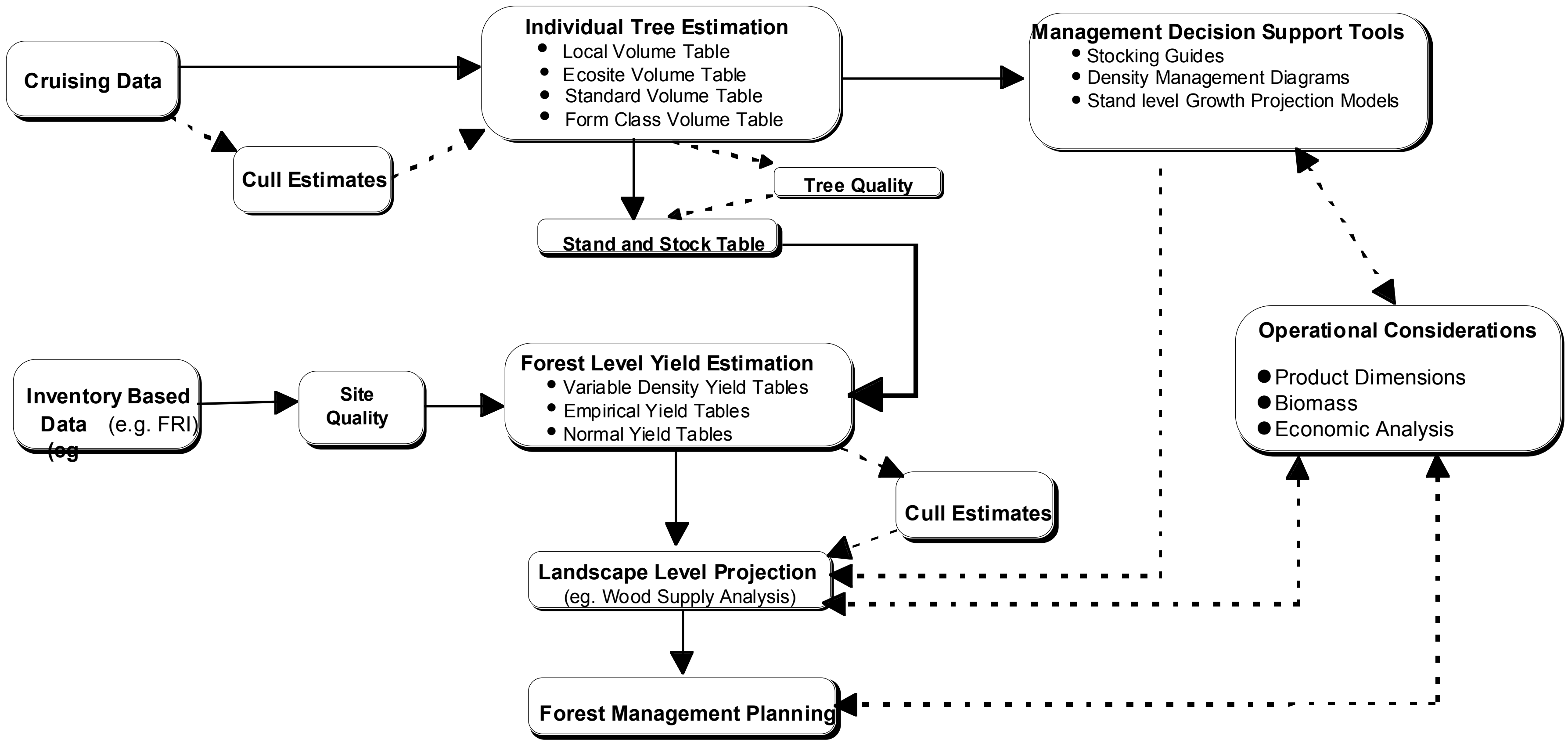

TABLE 5.0.1: Growth and yield sources

	Growth & Yield Tools	white pine	red pine	jack pine*	hemlock	white spruce	white cedar	red spruce
Site Productivity	Site Index	(Woods & Miller 1996	(Woods & Miller 1996	(Lewis *et al.* 1996)	(Frothingham 1915)	(Almemdag 1991)	(Johnston 1977)	(Meyer 1929)
	Site Class	(Plonski 1974)	(Plonski 1974)	(Plonski 1974)				
Individual Tree Estimation	Standard Volume Table	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)
	Local (Ecosite) Volume Table	(FEC database 1996)	(FEC database 1996)		(FEC database 1996)	(FEC database 1996)	(FEC database 1996)	
	Form Class Volume Table	(Berry 1981)	(Berry 1981)	(Berry 1981)		(Berry 1981)	(Berry 1981)	
	Cull Estimates	(Basham 1991)	(Basham 1991)	(Basham 1991)	(Basham 1991)	(Basham 1991)	(Basham 1991)	
Forest Level Estimation/ Forecasting	Normal Yield Tables	(Plonski 1974)	(Plonski 1974)	(Plonski 1974)			(Gevorkiantz/Duer 1939)	
	Empirical Yield Tables							
	Variable Density Yield Tables							
Management Decision Support	Stocking Guides	(Philbrook *et al.* 1973)	(Benzie 1977)	(Benzie 1977)	(Tubbs 1977)			
		(Lancaster & Leak 1978						
	Density Management Diagrams	(Smith & Woods *1997*)	(Smith & Woods *1997*)	(Archibald & Bowling 199				

* sources identified for jack pine apply to the Great Lakes-St. Lawrence forest types. Additional information is available in:
A Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario (1997).

5.1 Site Quality Assessment

A key factor in determining growth and yield response of trees and stands on a given landscape is the assessment of site quality. Site quality, the integration of soil (fertility, drainage, texture, depth), climate (temperature, precipitation), topography (elevation, aspect, etc.) and other factors, influence species composition and growth patterns. Information about site quality or potential site productivity is needed to make meaningful growth and yield forecasts (Vanclay 1994).

SITE INDEX

One of the most commonly used measures of site productivity for even-aged stands is site index (SI). Site index is a measure of height at a selected index age and varies according to species. Site index curve formulation is founded on the developmental height-age growth pattern of individual, or groups of dominant or codominant trees that are and always have been free from suppression. These trees reflect the potential (height) growth rate that an individual tree can have on a given piece of land. Height growth is relatively unrelated to stand density, yet closely correlated to volume. Thus, two stands with the same initial density, but different SI values will not produce equal volumes. The higher yield will occur in the stand with the greater SI value (Carmean *et al.* 1989).

Site index values in Ontario are usually described on a base age of 50 years. Measurements of stand age and stand top height are all that is required to determine SI. A stand with a height growth pattern intersecting 20 m at 50 years has a SI 20; another stand intersecting 22 m at 50 years has a SI 22. Site index curves developed within the last decade have been of a *polymorphic* form. This means that individual SI curves for a given species are flexible enough to reflect the distinct patterns of height-age growth indicative of their type (e.g. a white pine SI 13 growth curve may be more linear in form than a white ash SI 20). This flexibility provides a better definition of stand development patterns over time. Older versions of site index curves were of an *anamorphic* form. That is, they assumed that growth patterns were similar for all site indices.

Site index is often required as an input value for many of the growth models that have been developed in the United States, e.g. Fiber 3.0 [Solomon *et al. in press*], SILVAH [Marquis and Ernst 1992] and in Canada, e.g. PwSTIM (Larocque *(unpublished)*), white and red pine volume growth under uniform shelterwood management in Algonquin Park (Puttock and Bevilacqua 1995). These estimates of site productivity are often considered to be the “growth engines” of many growth models.

Site index curves for species covered in this guide are included with the individual species fact sheets in APPENDIX B.

SITE CLASS

Site class is a group of species specific site indices. It is a more generalized form of site quality classification than site index. Ontario has a 3-class system which is published in Plonski’s (1960, 1981) normal yield tables.

Ranges of SIs were divided into poor (Site Class 3), good (Site Class 2), better (Site Class 1) and best (Site Class 1a - for black spruce only) SI groupings. These classes were developed empirically by Plonski by hand fitting a curve through individual height-age measurements for multiple plots per species. Using this first curve as a guide, curves of the same shape were drawn one standard deviation above and below to create the boundaries of the site classes. Plonski's curves are anamorphic, meaning, similar shape for differing site classes or ranges of SIs. Today it is generally understood that anamorphic curves are less representative of stand height-age-site development patterns than polymorphic curves. Nevertheless, Plonski's Site Class curves still provide the fundamental site productivity classification system used in Ontario.

5.2 Individual Tree Estimation

VOLUME TABLES

Volume tables or equations provide estimates of individual tree volumes from previously established relationships among easily-measured tree characteristics such as diameter, height and tree form. *Standard*, *local* and *form-class* volume tables are used in Ontario. A summary of the inputs required for the use of various volume tables is presented in TABLE 5.0.2.

TABLE 5.0.2: Input requirements for various types of volume tables

TYPES OF VOLUME TABLES	REQUIRED INPUTS								
	Species	DBH	Ecosite	Total Height	Merch Height	Stump Height	Top Diam	Age	Cul 1%
Local Volume Table	r	r							
Ecosite Volume Table	r	r	r						
Standard Volume Table (GTV)	r	r		r					
Standard Volume Table (GMV)	r	r		r		r	r		
Standard Volume Table (NMV)	r	r		r		r	r	r	r
Form Class Volume Table	r	r			r				

Form-class volume tables have been in use in Ontario for over 60 years (Anon. 1930, 1948). They were used to estimate total and merchantable yields of individual trees, or sections of trees, and were usually based on Smalian's formula. In Ontario, Form-Class 65, 70, 75 and 79 tables have been used for a variety of species (Berry 1981; Staley 1991).

The calibration of form-class tables for local conditions requires the measurement of stem diameter at some specified upper height (usually the top of the first log [17' or 5.28 metres]). However, local form-class-diameter relationships were not easily constructed because of the difficulty in measuring upper stem diameter, and dealing with variations in tree form. Often, tree form was not measured and tables were arbitrarily assigned to each species (Honer *et al.*1983). This lead to the development of standard volume tables, which express the volume-diameter-height relationship without the need for tree form.

Standard volume tables for Ontario (Honer 1967; Honer *et al.* 1983) provide an estimate of the total inside-bark volume for individual trees. This method requires diameter at breast height (DBH) and total tree height to estimate volume. These tables are often well-documented and provide information on sample size, data range, construction methodology, date of preparation and measures of accuracy. Standard equations are developed by destructively sampling a large number of trees per species across the range it occupies. Honer's (1967, 1983) sampling was done throughout Canada. Standard volume tables for each species covered in this guide are presented with their respective fact sheets in APPENDIX B.

Local volume tables are a modification of standard volume tables based on a species DBH-height relationship in a defined area. Incorporation of the local DBH-height relationship eliminates the need to measure tree heights; volume is based solely on DBH. Local volume tables are commonly used during operational assessments of forest inventories. A common problem with the use of local volume tables occurs when resource managers use tables that have not been developed specifically for their site, species, and quality conditions. Managers should periodically calibrate their local volume tables by validating the diameter-height relationship.

Ecosite local volume tables are a modification of standard volume tables based on an *ecosite*-species DBH-height relationship. Incorporation of the local DBH-height relationship eliminates the need to measure tree heights. Consequently, volume is based solely on DBH within a determined ecosite. An explanation of how to develop ecosite local volume tables and an example is provided in APPENDIX C.

5.3 Forest Level Estimation and Forecasting

YIELD TABLES

Yield tables for *even-aged* stands are one of the oldest methods for estimating yields. Early yield tables provided only volume estimation at different ages for a given forest unit. Modern tables often include stand height, mean diameter, number of stems, stand basal area, and current and mean annual volume increments, in addition to accumulated volume estimates (i.e. yield). The most important use of yield tables are:

- to predict growth and harvestable volume
- to provide conceptual models of stand development.

Yield table estimates of growth and future harvest volumes are good enough to plan both the timing and marketing of the harvest (Philip 1994).

The three most common classes of yield tables are: normal, empirical and variable density.

Normal yield tables (e.g. Plonski 1960, 1981) provide estimates of expected yields tabulated by stand age and site index (or grouped into site classes) for ideal, fully stocked or "normal" forest stands (Vanclay 1994). They are usually derived by combining temporary sample plot data and stem analysis. The volume of an existing stand may be estimated with a normal yield table by adjusting the published yield values by a percentage of the expressed normality (based usually on basal area). Normal yield tables provide reliable estimates of potential yields for even-aged stands that are like the stands used to develop the tables, but estimates may be poor in natural stands whose age varies considerably from those used in table construction (Vanclay 1994).

For the purpose of this guide, the ecosites for even-aged **unmanaged** conifers in central Ontario have been sorted into three site classes: high, medium, and low productivity. These Ecosite Productivity Classes by Soil Types are presented in TABLE 5.0.3 and the Yield Estimates by Site Type are presented in TABLE 5.0.4. This table also presents some generalized growth and yield estimates for comparison purposes. Work is currently underway to refine estimates by ecosite.

Empirical yield tables are similar to normal yield tables in their construction and use. Their difference is that empirical tables are based on sample plots of average rather than full stocking. According to Husch *et al.* (1972), "the judgement necessary for selecting fully stocked stands is eliminated, simplifying the collection of field data". Yield tables developed in this manner display stand characteristics for the average stand density encountered in the collection of the field data.

Variable density yield tables include the additional variable of density, which permits data from partially stocked stands to be used in their development. This addition also means that variable density yield tables can be applied to stands regardless of their stocking. Recently published variable density yield tables in the Boreal forest (Bell *et al.* 1990) use a combination of stand density, stand age and SI in their presentation of yield information.

Ecosite yield tables based on research plot analysis are currently being developed to predict stand-level yield estimates. An example and methodology for the development of forest resource inventory (FRI) based forest level ecosite yield tables are presented in APPENDIX D. The curves depict the weighted-average species composition, site class allocation and stocking of each species occurring in the ecosite. The curves present net merchantable volume (NMV) estimates that have been reduced by a cull percentage estimated from the work of Basham (1991). These curves may be used as input into the long-term forest assessments required by the Forest Management Planning Manual (OMNR 1996), or for use in the Strategic Forest Management Model (SFMM) (Davis 1996). However, the user should construct unit-specific curves whenever possible, based on ground-truthed ecosite and yield estimates.

The Ecosite Yield Tables in APPENDIX D provide gross merchantable (m^3/ha) and net merchantable (m^3/ha) volumes at the normal stocking level (100 per cent). Resource managers are provided the opportunity to reduce the GMV estimates by their own cull percentage whenever they are available.

Stand and stock tables are quantitative descriptions of individual or groups of forest stands for forest inventory purposes. This approach is used to estimate the amount of usable wood for a variety of end-products, including pulpwood, fuelwood, or sawlogs. The stand and stock tables are also used to analyze stand structure in the development of intermediate thinning or final harvest prescriptions. The most common stand parameters measured include frequencies of species and diameter classes.

A stand table is used to present the number of trees by species for a forest, with data often expressed as basal area by diameter or height classes. Stand tables can be on a unit area basis, such as a hectare, or by the total area of a stand or forest. A stand table is useful for showing the stand structure (Husch *et al.* 1972).

Once harvest or thinning prescriptions have been developed, current stand yield by product class can be determined. Future stand growth can also be predicted within each diameter or size class, which provides more accurate assessments of future stand structure. Many growth models use this method of stand growth projection.

TABLE 5.0.3: Conifer ecosite productivity classes by soil type (*based on*: Southcentral FEC plot data)

	SOIL TYPE						
	S	S3	S4	S5	S6	S10	S12
	Very Shallow < 30 cm with LFH	Shallow-Deep MR: theta - 1 All Textures	Shallow - Deep MR: 2 - 5 Coarse Sandy	Shallow - Deep MR: 2 - 5 Fine Sandy	Shallow - Deep MR: 2 - 5 Coarse Loamy - Silty	Shallow - Deep MR: 2 - 5 Fine Loamy - Clayey	Deep Organic > 40 cm Organic Horizon
white pine	14.1 / 11.1 / 13.1	14.1 / 11.1 / 13.1	11.2	11.2	14.2		
red pine	12.1	12.1 / 13.1		12.2	12.2		
hemlock	28.1 / 30.1	28.1 / 30.1			28.2		
jack pine	13.1 / 15.1	19.1 / 11.1 / 13.1 / 15.1					
white cedar		30.1* / 21.1*			29	34	34
white spruce				18.2*	27.2* / 18.2*		
red spruce	no data	no data	no data	no data	no data	no data	no data

* **Preliminary Site Index assessment based on limited data.**

High
Medium
Low

TABLE 5.0.4: Yield estimates by productivity classes and ecosite-soil types (*based on*: southcentral FEC plot data)

	SI Range[1]	**White Pine** Ecosite-Soil Type	**40 yrs** MAI (m^3/ha/yr)	**40 yrs** Yield (m^3/ha)	**60 yrs** MAI (m^3/ha/yr)	**60 yrs** Yield (m^3/ha)	**80 yrs** MAI (m^3/ha/yr)	**80 yrs** Yield (m^3/ha)	**100 yrs** MAI (m^3/ha/yr)	**100 yrs** Yield (m^3/ha)
High	>=18	11.2-S5	5.7	227	6.2	371	5.8	465	5.3	527
Medium	14 to 17	14.1-S1, 14.1-S3, 11.1-S1, 11.1-S3, 11.2-S4, 11.2-S6	3.7	146	4.2	255	4.2	333	3.9	391
Low	<= 13	13.1-S1, 13.1-S3	1.6	62	2.3	136	2.5	202	2.5	249

	SI Range[1]	**Red Pine** Ecosite-Soil Type	**40 yrs** MAI (m^3/ha/yr)	**40 yrs** Yield (m^3/ha)	**60 yrs** MAI (m^3/ha/yr)	**60 yrs** Yield (m^3/ha)	**80 yrs** MAI (m^3/ha/yr)	**80 yrs** Yield (m^3/ha)	**100 yrs** MAI (m^3/ha/yr)	**100 yrs** Yield (m^3/ha)
High	>=21		7.5	299	6.5	391	5.5	443	4.7	474
Medium	15 to 20	12.1-S1, 12.1-S3, 12.2-S5, 12.2-S6, 13.1-S3	5.4	216	5.1	306	4.4	356	3.8	385
Low	<= 14		3.5	139	3.7	223	3.4	270	3.0	295

	SI Range[2]	**Jack Pine** Ecosite-Soil Type	**40 yrs** MAI (m^3/ha/yr)	**40 yrs** Yield (m^3/ha)	**60 yrs** MAI (m^3/ha/yr)	**60 yrs** Yield (m^3/ha)	**80 yrs** MAI (m^3/ha/yr)	**80 yrs** Yield (m^3/ha)	**100 yrs** MAI (m^3/ha/yr)	**100 yrs** Yield (m^3/ha)
High	>=20		5.0	200	4.2	252	3.4	271	2.7	274
Medium	16 to 19	19.1-S3, 11.1-S3, 13.1-S3, 15.1-S3	3.8	151	3.3	199	2.8	222	2.3	229
Low	<= 15	13.1-S1, 15.1-s1	2.2	90	2.3	138	2.1	166	1.8	177

	SI Range	**Eastern Hemlock[3]** Ecosite-Soil Type	**40 yrs** MAI (m^3/ha/yr)	**40 yrs** Yield (m^3/ha)	**60 yrs** MAI (m^3/ha/yr)	**60 yrs** Yield (m^3/ha)	**80 yrs** MAI (m^3/ha/yr)	**80 yrs** Yield (m^3/ha)	**100 yrs** MAI (m^3/ha/yr)	**100 yrs** Yield (m^3/ha)
High	>=14		(2.1)	(101)	(2.9)	(172)	(3.0)	(236)	(2.9)	(290)
Medium	10 to 13	28.1-S1, 28.1-S3, 28.2-S6, 30.1-S1, 30.1-S3, 30.2-S6	(2.0)	(81)	(2.4)	(143)	(2.4)	(196)	(2.4)	(237)
Low	<=9		(1.6)	(62)	(1.9)	(113)	(2.0)	(158)	(1.9)	(193)

TABLE 5.0.4: Yield estimates by productivity classes and ecosite-soil types (*based on*: southcentral FEC plot data)

		White Spruce[4]	**40 yrs**		**60 yrs**		**80 yrs**		**100 yrs**	
	SI Range[4]	Ecosite-Soil Type	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)
High	>=13	27.2-S6[7], 18.2-S5[7], 18.2-S6[7]	(5.2)	(110)	(5.3)	(242)	(4.8)	(333)	(4.3)	(392)
Medium	10 to 12		(2.8)	(110)	(2.3)	(191)	(3.2)	(253)	(3.0)	(298)
Low	<=9		(1.8)	(71)	(2.3)	(137)	(2.4)	(194)	(2.4)	(237)

		White Cedar[5]	**40 yrs**		**60 yrs**		**80 yrs**		**100 yrs**	
	SI Range	Ecosite-Soil Type	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)
High	12				4.1	244	3.7	294	4.1	329
Medium	9	34-S10, 34-S12, 29.2-S6, 30.1-S3[7], 21.1-S3[7]			3.0	182	2.8	227	3.2	257
Low	6				2.0	118	1.9	153	2.2	175

		Red Spruce[6]	**40 yrs**		**60 yrs**		**80 yrs**		**100 yrs**	
	SI Range	Ecosite-Soil Type	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)	MAI (m^3/ha/yr)	Yield (m^3/ha)
High		No data Available	(2.8)	(110)	(2.3)	(191)	(3.2)	(253)	(3.0)	(298)
Medium		No data Available	(1.8)	(71)	(2.3)	(137)	(2.4)	(194)	(2.4)	(237)
Low		No data Available	(0.6)	(25)	(1.2)	(72)	(1.5)	(119)	(1.6)	(158)

Note: MAI and yield values *from*: Plonski (1974), unless otherwise noted

1 (*from*: Woods and Miller 1996)

2 (*from*: Lewis *et al.* 1996)

3 No yield estimates available for eastern hemlock - Plonski's (1974) *tolerant hardwood* values are recommended.

4 No yield estimates available for white spruce - Plonski's (1974) *black spruce values for Site Class 1a, 1 and 2* are recommended.

5 (*from*: Johnston 1977)

6 No yield estimates available for red spruce - Plonski's (1974) *black spruce* values are recommended.

7 Preliminary Site Index Assessment - based upon limited data.

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6.0 Genetics

6.0 Genetics

by Fred N.L. Pinto and Dave Herr

This section provides a review of the importance and relevance of genetics to sustainable forest management, followed by information on the genetics of individual species.

6.1 The Importance of Genetics to Sustainable Forest Management

Genetic diversity is important for maintaining healthy tree populations that are able to respond favourably and adapt to changes or disturbances in their environment. Changes to genetic diversity occur through the creation of new genes (through mutation), and the loss of existing genes (through genetic drift in small populations and through elimination of populations). Humans can affect the rate of change in genetic diversity accidentally or deliberately, such as through the sustained selective removal of individuals in "high grading" harvesting operations, selection and propagation of certain individuals, or the introduction of new genetic material through unregulated movement of genetic material in artificial regeneration operations. Successful, sustainable forest management practices must include maintenance of natural levels of genetic diversity as a major priority.

6.2 How to Maintain and Conserve Genetic Diversity

Genetic diversity is the entire complement of genetic characteristics associated with populations or species. Genetic diversity drives, and is the result of, evolution, initiation of genetic mutation, gene migration and exchange, and natural selection (Yeatman 1996). The following considerations are inherent to the maintenance of genetic diversity (***see also*** Section 7.2.4.4 "Maintenance of Genetic Diversity"):

- **Identify, designate, and manage as large a natural population** as possible, while also considering other endemic species populations, using Ontario's seed zones. Seed zones are geographic areas with similar climatic conditions within which local plant populations are believed to have adapted.

- **Use Ontario's seed zones** to manage the movement of native tree seed and planting stock for artificial regeneration.

- **Limit the potential for inbreeding and genetic drift.** Both factors increase as the potential for related individuals to mate increases. Small, isolated populations of trees, such as white pine, pitch pine, hemlock, and red spruce are particularly vulnerable.

- **Maintain the genetic legacy** of the old forest into a new, young white pine, red pine or hemlock forest. The genetic legacy of the forest is maintained by ensuring that population viability (genetic diversity, reproductive success, *etc*.) is maintained within the residual population following harvesting and/or silvicultural operations.

6.2.1 White Pine

For conservation of white pine genetic diversity, forest managers will apply silvicultural prescriptions that emphasize large, well-stocked stands and populations that are growing on suitable sites. Regeneration must come from trees that have cross-pollinated with distantly or unrelated neighbors (Yeatman 1996).

6.2.1.1 Progeny tests and population differences

- White pine is a genetically diverse species across its native range, as shown by numerous progeny tests performed on white pine seed from different sources. For example, southern white pine sources grow more rapidly than other progeny at a number of different locations (Olson *et al.* 1981; Wendel and Smith 1990). However, the superiority of southern sources decreases at 45° north latitude (Garrett *et al.* 1973; Edge *et al.* 1991). One study demonstrated that sources from the Lake States, Ontario, and Quebec performed poorly in progeny tests, possibly because of an adaptation to a more continental, drier climate (Kuser 1987). Buchert (1994) reviewed 35 white pine provenance studies, and concluded that this species is highly variable across its range.

- Tests have shown progeny differences in air pollution sensitivity, cone production, winter injury susceptibility, and blister rust (*Cronartium ribicola* Fisch.) susceptibility (Leak *et al.* 1970; Anderson 1973; Genys 1978; Karnosky and Houston 1979). Other white pine populations are resistant to the white pine weevil (*Pissodes strobi* Peck) (Wendel and Smith 1990). However, caution must be used when interpreting these results. Provenance tests may be misleading because healthy seedling size is often dependent on initial seed size; seed from southern provenances is generally larger than those from northern provenances. This difference in seed size may cause observed progeny differences. Wendel and Smith (1990) suggest that local seed sources are still the best bet for successful white pine regeneration.

6.2.1.2 Races, varieties and hybrids

- Intra-specific variation at the taxonomic level for white pine seems relatively insignificant (Horton and Bedell 1960). Across its natural range in southeastern Canada and northeastern United States, *Pinus strobus* L. var. *strobus* is the only variety found. Only one other variety of white pine, called the Chiapas pine (*Pinus strobus* L. var. *chiapas*) exists; growing in the mountains of southern Mexico and Guatemala.

- Eastern white pine does, however, cross-pollinate and fertilize readily with some other *Pinus* species. These include: western white pine (*Pinus monticola*), balkan pine (*Pinus peuce*), blue pine (*Pinus griffithi*), Japanese white pine (*Pinus parviflora*), limber pine (*Pinus flexis*), and Mexican white pine (*Pinus ayacahuite*). *P. strobus* x *P. griffithi* crosses have been found to be more vigorous than *P. strobus* in Northern Ohio, and more winter hardy than *P. griffithi* alone (Kriebel 1972). Hybridization between similar species may lead to improvement of growth qualities and resistance to damaging agents.

6.2.2 Red Pine

Red pine is a very ancient species, displays relatively little variation in morphology, and is considered to be genetically very uniform (Fowler and Morris 1977; Mosseler *et al.* 1991; Mosseler *et al.* 1992). As a function of its low genetic variability, red pine is very self-compatible and self-fertile (Yeatman 1996). Because of inherent low genetic variability, large breeding populations are not as critical as for other species. Even single, isolated trees can produce self-fertilized offspring without any genetic depression. Most red pine today probably came from a refuge in the Appalachian mountains after the last glaciation (Wright 1964; Rudolf 1991).

6.2.2.1 Progeny tests and population differences

- Variation noted among different red pine populations is not likely due to genetics, but rather environmental factors. Progeny tests have shown that variation in progeny means from a single tree can be as great as, or greater than variation between population or provenance means (Rudolf 1991). One study in Ontario showed that red pine variation among stands was random in nature.

- Although red pine is relatively uniform across its range, some minor variations occur (Rudolf 1991):

  - an erect form with parallel, vertical branches
  - abnormally slender branches
  - suppressed lateral branch growth
  - dwarf trees
  - chlorophyll deficient seedlings
  - tetraploid seedlings.

6.2.2.2 Races, varieties and hybrids

- Provenance tests have shown some variation among different seed sources. Seeds from different sources show differences in survival rates, phenological traits, growth rates, photoperiodic response, and wood quality. Northern seed sources generally have smaller seeds with fewer cotyledons, fewer lammas, and lower frost sensitivity. No red pine hybrids exist. Attempts at artificial hybridization have failed, unless seeds are exposed to high doses of radiation.

6.2.3 Red Spruce

Red spruce has been severely reduced through human activity across its ecological range in Ontario (Gordon 1992). It currently exists as small isolated stands or individual trees.

6.2.3.1 Progeny tests and population differences

- Research results from Ontario are not currently available.

6.2.3.2 Races, varieties and hybrids

- Interspecific cross-pollination of red spruce pollen and ovulate cones has been performed with *Picea mariana, P. omorika, P. glehnii, P. orientalis, P. koyomai* and other species. Some black spruce - red spruce hybrids (*Picea mariana* x *Picea rubens*) do occur in nature (Gordon 1992).

6.2.4 Eastern White Cedar

Eastern white cedar is morphologically varied across its range.

6.2.4.1 Progeny tests and population differences

- Provenance tests have shown that some genetic variation exists among eastern white cedar populations.

6.2.4.2 Races, varieties and hybrids

- No races of eastern white cedar have been reported. No natural or artificial hybrids exist. However, there are at least 120 ornamental cultivars of eastern white cedar with different foliage color and growth habit.

6.2.5 White Spruce

Morphological variability and genetic diversity are high across white spruce's range, as shown by inbreeding depression after selfing, high heritability for polygenic traits such as height growth, and from studies using molecular biology and genetic markers. Because of this variability, extensive clearcutting may be expected to lead to population isolation, reduced gene flow between populations, reduced population sizes, and decreased genetic diversity.

Genetic management of white spruce includes identifying and maintaining large, diverse, uneven-aged stands growing with a mixture of other species (Yeatman 1996). Site, stand, and ecosystem characteristics will determine whether shelterwood, selection, or clearcut silvicultural systems are applied.

Because inbreeding decreases white spruce seed set, survival, and growth, silvicultural prescriptions must optimize opportunities for cross pollination (Ying 1978).

6.2.5.1 Progeny tests and population differences

- White spruce from southern sources are faster-growing and flush earlier than their northern counterparts. Alaskan trees are often dwarfs. Ecotypic variation is shown by white spruce trees growing on limestone derived soils. Variations in optimal germination temperatures exist among different progenies. Because of these variations, it is important to collect seeds locally. Considerable genetic variation exists among planting stock. For this reason, it is important to carefully plant larger, healthier white spruce stock, as it is likely to outgrow smaller plants for at least the first 20 years.

- One high-yielding white spruce provenance grows near Beachburg, Ontario, in the Ottawa valley. This provenance has done exceedingly well in the Lake States, New England, and southeastern Canada.

- Self-pollination causes decreases in vigour, height growth, survival rates, and reduced seedset (Coles and Fowler 1976; Ying 1978). To reduce selfing in future generations, seed collection for regeneration purposes should be collected from trees at least 30 m apart (Coles and Fowler 1976; Cheliak *et al.* 1985). Seed sources should be mixed well to simulate natural genetic structure (King and Dancik 1984).

6.2.5.2 Races, varieties and hybrids

- Four varieties of white spruce exist: *Picea glauca* var *glauca*, *P. glauca* var *albertiana*, *P. glauca* var *densata* and *P. glauca* var *porsildii*. Hybrids of black spruce and white spruce are rare in its southern range (Little and Pauley 1958; Riemenschneider and Mohn 1975). However, they become more common to the north, especially in Alaska and the forest tundra tree line (Nienstaedt and Zasada 1991).

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7.0 Ecological Foundations for Silviculture

7.0 Ecological Foundations for Silviculture

by Fred N.L. Pinto

Today there is consensus in society that forests be managed sustainably (Ontario Forest Policy Panel 1993). This means that silvicultural practices incorporate more holistic understanding of the ecology of forest ecosystems (not just trees) and attempt to emulate natural processes that shaped Ontario's forest ecosystems.

Wildfire and wind appear to have been the dominant agents of disturbance in most of the Great Lakes-St. Lawrence conifer forest prior to human intervention. Both their effects were extremely variable. Catastrophic wind and fire events ranging from tens to thousands of hectares in size created large areas suited to the establishment and growth of even-aged forests of intolerant conifers and hardwoods such as jack pine, black spruce, red pine, poplar and white birch (e.g. ES 19). Moderate intensity understory fires tens to hundreds of hectares in size created ideal conditions for the establishment and growth of even-aged cohorts of mid-tolerant conifers such as white pine beneath residual canopies of veterans (e.g. ES 11). Fine scale wind events blew down individual trees or groups of trees. These gaps created conditions that enabled established shade tolerant conifers such as hemlock, red spruce, eastern white cedar and balsam fir to perpetuate themselves in mixtures with other tree species (e.g. ES 21).

The silvicultural practices applied in the Great Lakes-St. Lawrence conifer forest tend to emulate some important aspects of natural disturbance processes (*see* Section 7.2 "Silvicultural Systems"). For example, clearcutting and seed tree cutting produce relatively large forest openings with high light levels similar to large catastrophic wind or fire events. Shelterwood cutting tends to emulate the light conditions produced by moderate intensity understory fires. Group-selection tends to emulate the light conditions produced by tree-fall gaps created by fine scale wind events. However, there are also significant differences between the traditional application of silvicultural systems and natural disturbances. For example, the traditional application of the clear cut system could result in the complete removal of the overstory in one cut. Natural disturbances such as fire may leave some live trees and large amounts of coarse woody debris within the burn perimeter. Conventional application of silvicultural systems has been modified to more closely emulate the outcomes of natural disturbances (***see*** Section 7.2.4 "Modifications to Conventional Silvicultural Systems" and Section 8.0 "Integrating Timber and Wildlife Habitat Management").

Following natural disturbance, regeneration is provided by propagules from trees that survived the disturbance or from seedlings or saplings that were established on the site prior to the disturbance. Regeneration in managed stands of the Great Lakes-St. Lawrence conifer forest follow the same pattern (***see*** Section 7.4 "Renewal"). In shelterwood or seed tree cuts, trees retained to provide seed are those that would have likely survived fire (large, vigorous, dominant and co-dominant trees). Moreover, advanced regeneration is protected during felling and skidding (***see*** Section 9.0 "Harvesting Considerations").

Other silvicultural treatments may be needed to ensure that management activities emulate natural disturbance. For example, shelterwood harvesting may result in a canopy closure that emulates conditions created by moderate-intensity understory fires. The new light conditions may be favourable for the establishment and growth of mid-tolerant conifers. However, fire tends to expose mineral soil, a preferred seedbed for species such as white pine. To emulate this effect, site preparation activities are often required to complement the harvest cut (***see*** Section 7.3 "Site Preparation").

Natural disturbance such as fire also reduces the amount and vigour of understory vegetation, creating conditions for the establishment and growth of fire-adapted tree species such as white pine. Silvicultural practices attempt to emulate this control of competing vegetation through the use of prescribed fire or chemical or manual tending (***see*** Section 7.5 "Stand Maintenance").

The effects of forest management activities can differ from those of natural disturbances in a variety of ways. For example, heavy equipment used during harvest or site preparation can cause soil compaction, rutting, and erosion. While this can never be completely eliminated, operations must follow guidelines to minimize site impacts (***see*** Section 9.0 "Harvesting Considerations"). Similarly, harvesting removes woody material from the site and may also rearrange the distribution of woody material on the site. Forest managers may ameliorate the effects of nutrient loss due to the removal of wood from the site by carefully choosing harvest rotation ages, and harvest and regeneration intensity for each forest unit or ecosite (***see*** Section 7.5 "Stand Maintenance", Section 7.3 "Site Preparation" and Section 8.0 "Integrating Timber and Wildlife Habitat Management").

Moreover, conventional application of these silvicultural systems may not ensure that managed forests will have all the aspects of composition and structure that function as wildlife habitat compared to forests created by agents of natural disturbance. For example, natural disturbance such as fire creates large numbers of standing dead and declining trees that are required by a variety of cavity-using wildlife species. While managed forests may not have as many standing dead and declining trees as naturally disturbed forests, guidelines are prescribed that ensure that minimum requirements of cavity-users and other wildlife with special habitat needs will be met (***see*** Section 8.0 "Integrating Timber and Wildlife Habitat Management").

Finally, application of these systems on a stand-by-stand basis does not ensure that forested landscapes will have the composition, structure, and function created by natural disturbances. Managers must consider rotation age and size, shape, and dispersion of cut blocks to emulate the mosaic of age classes, forest types, and landscape patterns created by natural disturbance (***see*** Section 8.0 "Integrating Timber and Wildlife Habitat Management").

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7.1 Prescription Development

7.1 Prescription Development

by Fred N.L. Pinto

To achieve management objectives, a forest manager may have to implement a number of treatments in a specific order to produce the desired stand and site conditions. On Crown lands in Ontario, forest managers are required to describe the series of treatments for each broad grouping of forest cover (forest unit) and ecosite (OMNR 1996). These generic treatments are called silvicultural ground rules. Forest stands are variable. Each has its own unique combination of vegetation abundance and structural features. Because of this variation, forest managers are required to prepare Forest Operation Prescriptions. This section describes how silvicultural ground rules and Forest Operation Prescriptions can be developed.

7.1.1 Silvicultural Ground Rules

Silvicultural ground rules describe the treatment options that are available to meet forest objectives. They consist of a list of the various combinations of appropriate silvicultural systems, harvest methods, logging methods, renewal treatments, tending treatments and management standards for each forest unit and ecosite grouping (***see*** TABLE FMP-10 on page A-55 in OMNR [1996]).

This document must be used in the preparation of silvicultural ground rules during the preparation of Forest Management Plans. Table 7.1.1 may be used to locate suggested relevant information needed to develop silvicultural ground rules.

TABLE 7.1.1: Location of suggested relevant information required to develop silvicultural ground rules

TASK	REFER TO SECTION
Developing Forest Units	Section 2, 3, 5, 6 and 8
Describing Site Types	Section 3.3 and Appendix A
Selecting Silvicultural Systems	Section 7.2, 8 and Appendix E
Selecting Harvest and Logging Method	Section 7.5, 8, 9, 10 and Appendix E
Selecting Site Preparation Treatment	Section 7.3, 8 and Appendix E
Selecting Regeneration Treatment	Section 7.4, 8 and Appendix E
Selecting Tending Treatment	Section 7.5, 8 and Appendix E
Developing Regeneration Standards	Section 10
Describing Future Forest Unit	Section 2, 3 and 6
Describing Future Stand Development	Section 4 and 5
Describing Future Stand Characteristics	Section 2, 3, 6, 7 and 8

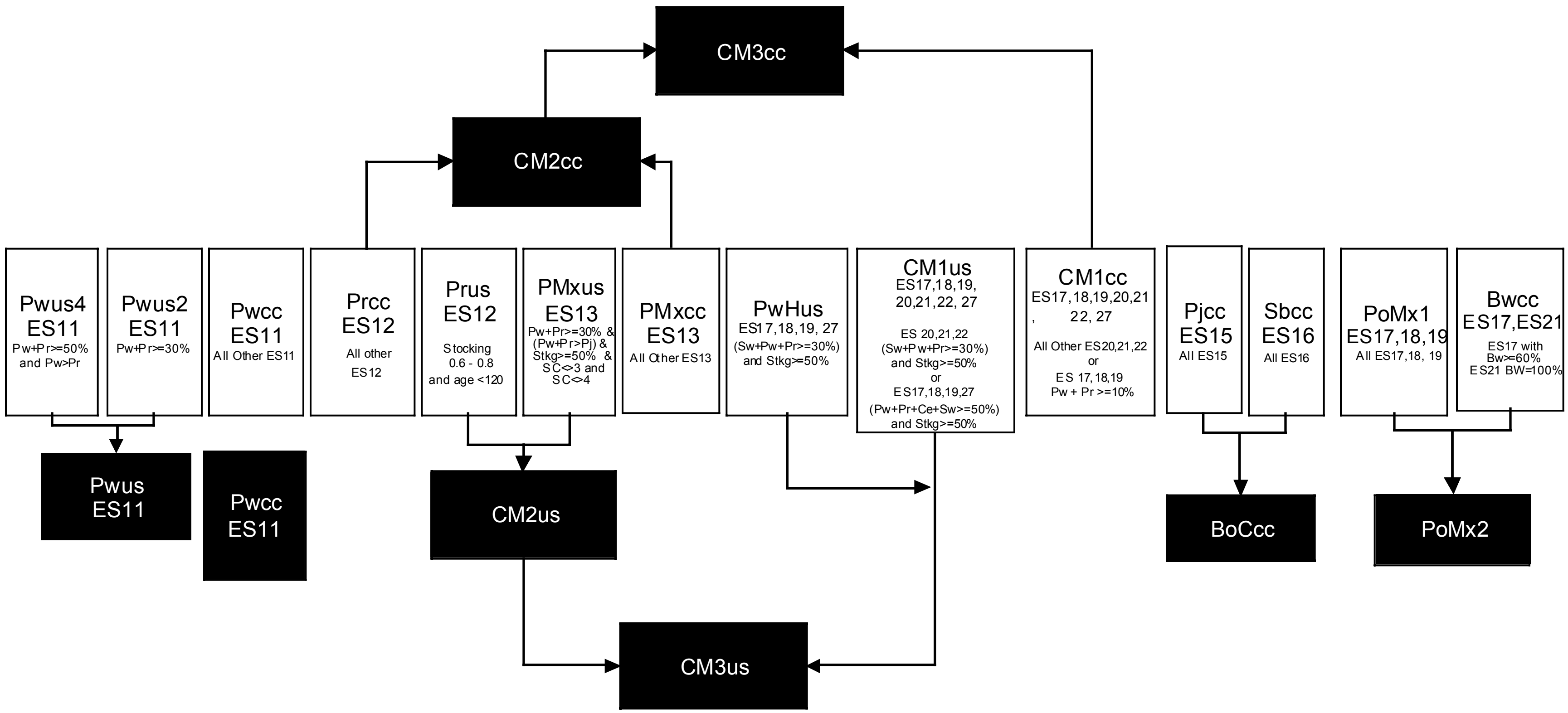
Information contained in Section 2 to Section 6 can be used to obtain an understanding of the Great Lakes-St. Lawrence conifer forest ecosites and the reproductive and growth adaptations of their constituent plant species. This information may be used by the manager to create forest units by selecting appropriate ecosite groupings. A forest manager may choose to group ecosites that will be treated similarly and produce similar stand structural characteristics and plant abundance (tree species composition) at specific times.

Suggested ecosites and species composition criteria that may be used to create forest units are described in Figure 7.1.1 a and b. For example, EcoForest Unit Pqus4 is made up of ecosites 14 and 23. This forest unit has stands that have a stocking of at least 70 per cent. The stands in this forest unit are composed of at least 50 per cent red oak and white pine, where white pine is found in higher proportions than oak. The forest units describe in Figures 7.1.1a and b were developed by planning teams working on the 1999 forest management plans for the Nipissing Forest, Lanark Management Unit and Parry Sound District in co-operation with staff from Southcentral Sciences Section, North Bay.

A forest manager may choose to split or combine ecosites based upon local objectives. For example Figure 7.1.1a suggests two levels of aggregation. At one level, the forest manager may choose to split white pine and red oak ecosites into two forest units (EcoForest Units PQus4 and Qrus2). Alternatively, the forest manager, based upon local forest conditions and objectives, may choose to combine them into one forest unit (EcoForest Unit PQHus).

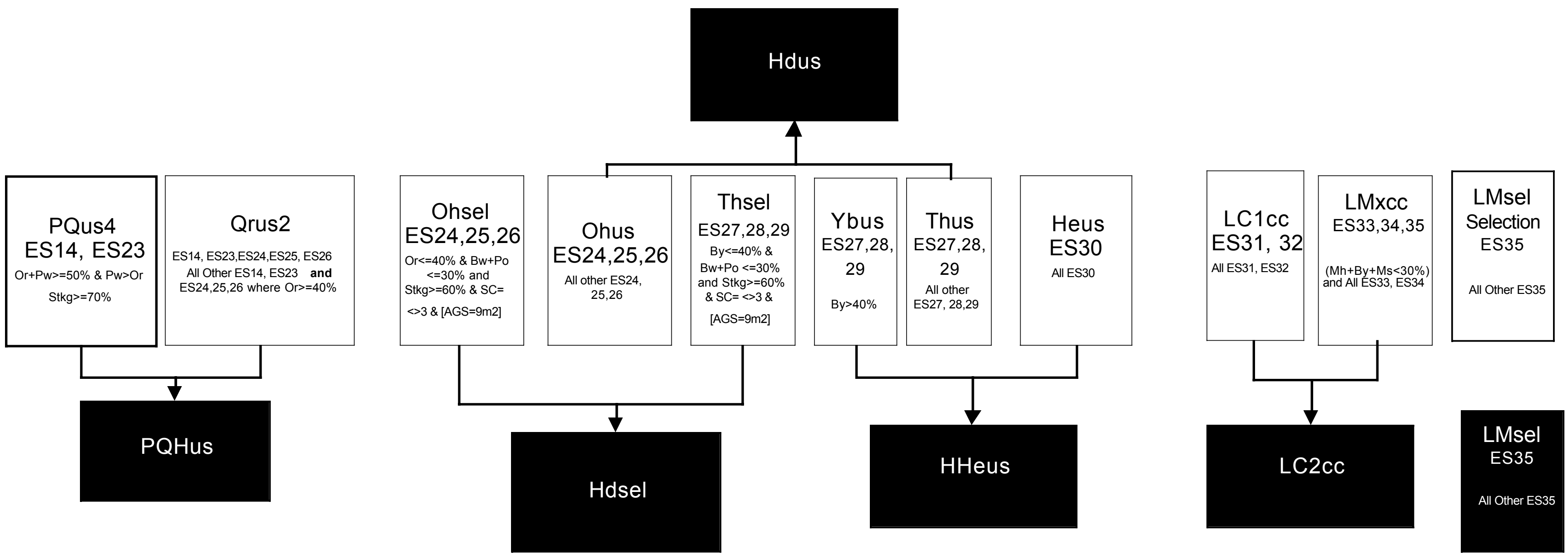
Information contained in Sections 7.2 to 7.5.1.4 must be used to develop the silvicultural treatment package. These sections describe how stand and site conditions may be changed to create conditions that will achieve the desired future stand characteristics within a prescribed period of time. Local knowledge derived from well-planned experimental studies and documented results from operational treatments may be used to modify the treatments or treatment combinations.

FIGURE 7.1.1: Suggested ecoforest units and potential levels of aggregation



Item	Forest Unit Name	Silvicultural System	Item	Forest Unit Name	Silvicultural System	Item	Forest Unit Name	Silvicultural System
CM3cc	Conifer-Mixedwood3	clear cut	PMxus	Pine-Mixedwood	uniform shelterwood	Bwcc	White Birch	clear cut
CM2cc	Conifer-Mixedwood2	clear cut	PMxcc	Pine-Mixedwood	clear cut	Pwus	White Pine	uniform shelterwood
Pwus4	White Pine	4-cut shelterwood	PwHus	Pine-Hardwood	uniform shelterwood	Pwcc	White Pine	clear cut
Pwus2	White Pine	2-cut shelterwood	CM1us	Conifer-Mixedwood1	uniform shelterwood	CM2us	Conifer-Mixedwood2	uniform shelterwood
Pwcc	White Pine	clear cut	Pjcc	Jack Pine	clear cut	CM3us	Conifer-Mixedwood3	uniform shelterwood
Prcc	Red Pine	clear cut	Sbcc	Black Spruce	clear cut	BoCcc	Boreal Conifer	clear cut
Prus	Red Pine	uniform shelterwood	PoMx1	Poplar-Mixedwood1	clear cut	PoMx2	Poplar-Mixedwood2	clear cut

FIGURE 7.1.2: Suggested ecoforest units and potential levels of aggregation



Item	Forest Unit Name	Silvicultural System	Item	Forest Unit Name	Silvicultural System	Item	Forest Unit Name System	Silvicultural
Hdus	Hardwoods	uniform shelterwood	Ybus	Yellow Birch	uniform shelterwood	PQHus	Pine-Oak shelterwood	uniform
PQus4	Pine-Oak	4-cut shelterwood	Thus	Tolerant Hardwoods	uniform shelterwood	Hdsel	Hardwoods	selection
Qurs2	Oak	2-cut shelterwood	Heus	Hemlock	uniform shelterwood	HHeus	Hardwood-Hemlock shelterwood	uniform
Ohsel	Other Hardwoods	selection	LC1cc	Lowland Conifer	clear cut	LC2cc	Lowland Conifer 2	clear cut
Ohus	Other Hardwoods	uniform shelterwood	LMxcc	Lowland Mixedwood	clear cut	LMsel	Lowland Mixedwood	selection
Thsel	Tolerant Hardwoods	selection	LMsel	Lowland Mixedwood	selection			

Suggested silvicultural options for each of the ecosites on which the management of Great Lakes-St. Lawrence conifers is planned are described in APPENDIX E “Silvicultural Option Tables”. These option tables list the treatments that are currently considered ecologically appropriate.

Forest managers should determine how well the possible silvicultural treatment packages lead to the achievement of the objectives for the forest. For example, a manager may want to know what emphasis must be placed on the retention and renewal of certain tree species in order to meet forest biodiversity objectives. For example, consider the state of red spruce in Ontario. Red spruce populations have been severely reduced across its ecological range in Ontario (Gordon 1992). Forest managers should strive to retain this species over other tree species. Similarly, restoration of this species may be required. This should be reflected in the silvicultural treatment regime for central Ontario ES 30 and ES 21.

The consequences of a treatment package and the level to which it is applied should be evaluated using an appropriate forest-level simulation computer model. The results of the simulations will provide the forest manager and the public some idea of how their planned activities may affect the achievement of forest objectives and targets.

7.1.2 Forest Operations Prescriptions

The Crown Forest Sustainability Act (RSO 1995) requires that forest operations in a Crown forest be conducted in accordance with a Forest Operations Prescription. A Forest Operations Prescription (FOP) is a specific treatment package to be applied to an individual forest stand or group of stands (i.e. an operating block) which is selected from the appropriate silvicultural ground rules in an approved Forest Management Plan. Forest Operations Prescriptions must be certified by a Registered Professional Forester.

The objectives of management in the conifer forests of the Great Lakes-St. Lawrence forest region are diverse and include a range of potential silvicultural treatments. The system of stand analysis (using a pre-harvest assessment) chosen to develop a Forest Operations Prescription must provide the forest manager with a high level of confidence in terms of the identification and quantification of criteria used to decide upon the most appropriate management approach.

Less formal approaches to pre-harvest assessment may be appropriate where:

- stand conditions are well-understood
- management approaches are fairly consistent
- levels of variability are anticipated and successfully dealt with as part of the normal fine-tuning of prescriptions by well-trained forest workers at the time of the operation.

Pre-harvest assessments of more intensity may be required:

- in areas exhibiting variable levels of quality, stocking, structure or species content

- in areas with unreliable inventory

- in areas where an error in judgment related to choice of harvesting system will have a significant impact on attainment of stand level objectives.

A pre-harvest assessment can ensure that incorrect, missing or unique conditions found in an operating block are considered before operations commence. Such a practice has the following benefits:

- it provides opportunities to identify values, such as stick nests, that are not recorded in existing inventories

- it provides an opportunity to verify the accuracy of the Forest Resource Inventory

- it provides an opportunity to prevent potential conflicts between forest users

- it reduces the potential of environmental degradation, such as rutting and erosion

- it allows for better scheduling of operations which can improve productivity

- it minimizes the costs of harvesting, regeneration and maintenance, and provides opportunities to verify progress in meeting site and forest objectives

- allows operations to be budgeted more accurately and determines in advance which stands or blocks are not feasible to operate in.

The stages of an intensive pre-harvest prescription are described in Pinto *et al.* (*in prep.*). Briefly, these stages involve:

7.1.2.1 Evaluation of existing data and plans

- reviewing the forest-level objectives and silvicultural ground rules for the forest units and ecosites expected in the operating block

- reviewing values maps for the proposed operating block.

7.1.2.2 Field inspection

- confirm forest unit, ecosite, inventoried values and stand characteristics. An example of a form for data collection and documentation is described in APPENDIX F

- if selection or shelterwood silvicultural systems are planned, stand structure may be quantified using the form described in APPENDIX F.

7.2.1.3 Development of site-specific targets

- Site targets are quantified descriptions of future site tree species composition, structure and function, such as the number of live cavity trees per hectare, or volume of wood by quality class per hectare by a certain time period (Pinto *et al.*[*in prep.*])

- To evaluate and develop site targets for stands that will be managed using the shelterwood or selection silvicultural systems (***see*** Anderson and Rice [1993]) for tolerant hardwood stands. For Great Lakes-St. Lawrence conifer stands, a diameter distribution for each tree species may be recorded on the form shown in APPENDIX F to obtain a description of the existing stand structure. Existing tree quality, and stocking may be derived using information described in Section 4.0 "Quality Development in Trees" and Section 5.0 "Stand Growth and Yield" respectively. This information may be used to set stand structure, quality, and stocking targets.

7.2.1.4 Prescription formulation and implementation

- compare the site and stand description obtained from the site inspection with the information documented in the Forest Management Plan

- update information as per requirements of the *Forest Management Planning Manual* and select the appropriate treatment package

- conduct and record operations described in the site plan

- ensure all current regulations are adhered to prior to conducting operations; for example, prescribed burning and the application of herbicides require additional planning, approval and documentation.

7.1.2.5 Monitoring and evaluation

- a pre-harvest prescription program provides information on the intent, rationale, site and stand characteristics, and treatments. Some of this information is required to compare the expected and actual results (OMNR 1996 ***see*** Section C, "Monitoring and Reporting"). Information garnered from this process is used in the development of future silvicultural ground rules.

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7.2 Silviculture Systems

7.2 Silvicultural Systems

by Fred N.L. Pinto, Al S. Corlett, Brian J. Naylor, Andrée E. Morneault, Dan F. Galley, J. Steve Munro and Jeff Leavey

A silvicultural system is a planned program of silvicultural treatments carried out during the entire "life" of a stand for the purpose of controlling establishment, composition, and growth of the stand. Silvicultural systems are divided into several categories in a hierarchical system (***see*** Smith [1986]; Matthews [1992] for a description of the method and rationale used to describe silvicultural systems). At the highest level, silvicultural systems are grouped according to whether the intent is to promote an even-aged or uneven-aged forest.

The choice of an even-aged or uneven-aged method is based primarily on:

- the silvics of the species of interest (***see*** Section 3.4 "Silvics of the Great Lakes-St. Lawrence Conifers")
- the current condition of the stand as affected by past management or natural influences
- the stand's potential as indicated by ecosite
- management objectives for the forest.

Only species that have adaptations to establish and grow in small openings within a forest stand, such as hemlock or red spruce, may be managed under either an even-aged or an uneven-aged method. Those species with adaptations to establish and grow in larger stand openings, such as white and red pine, white spruce and northern white cedar, are most efficiently regenerated and grown under even-aged methods.

The silvicultural systems are briefly described below:

EVEN-AGED METHODS

- Clearcut system

  A silvicultural system of regenerating an even-aged forest stand in which new seedlings become established in fully exposed micro-environments after most or all of the existing trees have been removed. Regeneration can originate naturally or artificially. Clearcutting may be done in blocks, strips or patches (OMNR 1996).

- Shelterwood system

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

UNEVEN-AGED METHODS

- Selection system

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 a cutting cycle. Artificial regeneration is generally not required (OMNR 1996).

Any of these systems will allow a variety of possible modifications (e.g. strip, patch) to suit specific conditions, but the same basic objectives are shared. It is expected that the silvicultural system selected will vary with different stand and site conditions, both in terms of appropriate modifications to the systems, and in terms of the degree of application or follow-up. Management objectives, stand accessibility, environmental concerns and funding will also contribute to some variability in application of these systems. A mosaic of stand conditions will result. While a degree of variability is inherent in managing Great Lakes-St. Lawrence conifer forests on different site types and across different jurisdictions, a consistent rationale that employs the same factor evaluation should ensure consistent policy application.

The experience and local knowledge of the field forester and all other persons involved in the implementation of a silvicultural system will contribute greatly to the successful application of the method selected for a particular stand. The complexity of some silvicultural activities and certain aspects of on-the-ground implementation of these activities require that a correspondingly intensive level of training be given to forest technicians and forest workers. In addition, an adequate funding base must be available to apply silvicultural treatments. This is especially important for the development of pre-harvest prescriptions and the application of tree-marking technology. These factors will be dealt with in detail in a companion report, *A Tree-Marking Guide for Ontario* (under development).

7.2.1 Clearcut System

Clearcutting removes all or most of the overstory in a single operation and provides for the establishment of a new even-aged forest. Some of the overstory may be retained to provide a seed source (clearcut with seed tree silvicultural system) or for ecological reasons, such as providing wildlife habitat (clearcut with standards silvicultural system). Maximum cutover size is critical if natural regeneration is sought as none of the Great Lakes-St. Lawrence conifer tree species reproduce very well vegetatively or are effective seed-bankers.

In many cases, a substantial number of trees are left uncut within the cleared area. If the residual trees are expected to interfere with the establishment and development of the new stand, then the residual stems must be controlled. They may be treated by girdling, felling or killed during site preparation.

Features of the clearcut system:

- well-suited to the management of shade intolerant species adapted to take advantage of major disturbances

- harvesting operations are made more cost-efficient with immediate availability of higher volumes per unit area, lower road costs, and lower layout and transportation costs

- no merchantable trees left that could deteriorate, although significant loss of advance regeneration may occur

- most silvicultural input and investment follows the harvest

- simple regulation of cut by area.

Challenges related to the implementation of the clearcut system:

- competition from intolerant species is intense

- unmerchantable species and individual trees may be left on site, creating competition for crop tree species or higher regeneration expense

- entire site exposed at one time creating microclimatic conditions unsuitable for the germination and survival of some tree species

- potential for erosion, runoff (on slopes), and aesthetic problems

- high investment in site preparation, artificial regeneration and tending may be required to meet forest objectives.

Variations of the clearcut system include:

7.2.1.1 Conventional clearcut

Involves the complete removal of the overstory from a large contiguous area. This occurs in a single operation.

7.2.1.2 Clearcut with standards

Standards refer to live trees that are retained within the cleared area to meet a specific purpose. For example, the retention of veteran red and white pine are standards.

7.2.1.3 Seed-tree (clearcut with seed trees)

Usually trees of seed-bearing age are evenly spaced to provide the seed supply required over the regeneration period. For example, red pine seed is usually distributed within one tree-length of the parent tree. Red pine seed trees are usually spaced about a tree-length apart where available.

Although there may be visual similarities to shelterwood treatments, the difference is that remaining crown cover provides an insignificant amount of shade following a clearcut with seed trees. Managers must be aware that treatment failures usually result from inadequate numbers and fecundity of seed trees, or the failure to invest in required site preparation following harvest, and should modify their operations accordingly. The retention of residuals creates more structural diversity than that found in unmodified clearcuts.

7.2.1.4 Patch clearcut

The physical dimensions of clearcuts can be modified to accommodate site and stand variability making this approach well-suited to operating in broken terrain or for use in stands that lack uniformity. Patch configurations are often a reflection of the predominant mosaic in the original forest and can vary greatly in size, placement and association with other approaches. For instance, where white pine, red pine and jack pine grow together naturally, the manager can favour any or all three tree species, depending on the prevailing site condition, by establishing clearcut patches within a stand managed predominantly under the uniform shelterwood system. When direct seeding or planting is anticipated, seed source is not required and patch size is less critical but harvest pattern and type should attempt to emulate the intensity and pattern of natural disturbances usually associated with the particular ecosite. Patch clearcuts provide more edge-effect than rectangular cuts (e.g. strips, blocks).

7.2.1.5 Progressive strip clearcut

The area is compartmentalized and adjacent strips are cut in sequential order. Strip and block clearcuts are characterized by rectangular boundaries. The strip or block clearcut is applicable in relatively flat, uniform terrain or where stand conditions are relatively uniform. The uncut strips can provide a seed source and may shelter regeneration.

GROWING CONDITIONS CREATED

Application of the clearcut system provides light conditions similar to those following a severe burn. Natural disturbance can be further emulated through consideration of natural fire pattern and size distribution, requirements for leave trees or uncut blocks, site disturbance, etc.

The clearcut system is, therefore, most suited to light-demanding species such as red pine, although the attainment of long-term stand objectives depends upon retention of a sufficient seed source, availability of a receptive seedbed and timely management of competition. The clearcut system may also be used where artificial regeneration is planned. In these cases the species selected to restock the site must be adapted to grow in the open conditions created by a clearcut.

White spruce and white pine often occur as a minor component of stands dominated by other species (e.g. ES 11.1, 11.2, 13.1, 13.2), and the forest manager must consider the silvical requirements of their associates in selecting the silvicultural system. Thus, if the stand is dominated by intolerant species such as jack pine or poplar, a modified clearcut approach would be an option, although a more specific outline of considerations follows (***see*** Section 7.2.4 "Modifications to Conventional Silvicultural Systems").

7.2.2 Shelterwood System

The shelterwood system involves the gradual removal of the overstory by a series of partial cuts that extend over a small portion of the rotation (***see*** Section 7.2.4 "Modifications to Conventional Silvicultural Systems"). The degree of residual crown closure, and species composition of the overstory may be modified to encourage or discourage establishment and development of particular species. Natural regeneration becomes established under the protection of the older stand, which is removed as required to release the established regeneration. This system is characterized by the establishment of a new crop before completion of the preceding rotation (Smith 1986). Residual trees act as a seed source and will increase in size and value during the reproduction phase. On some ecosites, artificial regeneration may be used to augment natural regeneration.

Features of the shelterwood system:

- reproduction is more uniformly established than with modifications of the clearcut system, due to a uniformly distributed seed source

- residual overstory modify climatic extremes, reducing seedbed desiccation and losses of succulent seedlings from heat injury and risk of frost and summer radiational injury.

- aesthetic quality may be maintained

- silvicultural costs may be lower as a result of reduced tending requirements, and greater likelihood of natural regeneration.

Challenges related to the implementation of the shelterwood system:

- more technical skill is required (in terms of layout and harvest operations) than for clearcut operations

- careful logging practices must be applied in order to limit logging damage to residuals and regeneration

- harvest and site preparation operations must be designed to accommodate and limit damage to residuals

- immediate logging costs are higher than for clearcutting.

Normally the shelterwood method requires a minimum of two cuts. Under intensive practice, several cuttings are made in the gradual process of establishing regeneration, releasing the reproduction and removing the mature stand. The sequence of treatments may involve two or three different kinds of operations, usually in the following order:

- Preparatory cut: removes undesirable seed-source species and low-quality individuals and permits crown expansion of potential seed producers

- Seed or regeneration cut: further canopy reduction carried out preferably in, or just prior to, a seed year, which allows site preparation if necessary and creates the proper light condition for germination and establishment

- Removal cut: residual stand is removed in one or more operations, to release well-established regeneration.

Cuts may vary in configuration and number, although consideration has to be given to the above stages in any modifications to the shelterwood system.

Variations of the shelterwood system include:

7.2.2.1 Uniform shelterwood

Canopy is (periodically) opened uniformly throughout the entire stand. This method is most applicable in instances where seed source, site or seedbed protection is essential, and aesthetics are a consideration.

7.2.2.2 Strip shelterwood

Canopy is opened in progressive stages in narrow (usually no more than _ tree height wide) successive strips, arranged sequentially or in shelterwood strips. It may be suitable in very dense stands where the uniform shelterwood system would be difficult to implement. It may also be used to restore Great Lakes-St. Lawrence conifers into stands currently occupied with low grade hardwoods.

7.2.2.3 Group shelterwood

Canopy is opened progressively in concentric bands from an original centre (normally an area of advanced regeneration) in the stand.

The strip shelterwood and group shelterwood variations are fairly difficult to implement operationally, and have seldom been implemented successfully in the Great Lakes-St. Lawrence conifer forest. It is expected that most field applications of this system will continue to be uniform shelterwood. Discussion of the shelterwood system in this guide will therefore assume that the uniform shelterwood variation is intended. However, the principles would also apply to strip and group shelterwood variations, if those approaches were undertaken.

GROWING CONDITIONS CREATED

The shelterwood system provides an environment of partial shade from a high, evenly-distributed crown canopy, available seed-producing trees, and a forest floor protected to some extent from temperature extremes and desiccation. When required, associated site preparation treatments can modify seedbed conditions and moderate competition levels.

These conditions emulate in many ways the environments for which some of the principle Great Lakes-St. Lawrence conifer species are naturally adapted. Uniform shelterwood is, therefore, normally the system of choice for the management of the mid-tolerant white pine, white cedar and white spruce. White spruce is similar to white pine in its silvical requirements, including shade tolerance level and preferred seedbed condition, and as an associate with white pine, will regenerate and develop readily in a shelterwood environment.

Shelterwood is one viable option for the management of light-seeded, shade-tolerant species such as hemlock. Hemlock is able to establish under partial shade provided by 60 per cent crown closure.

While the system can be applied to shade-intolerant species such as red pine, considerable attention to overstory condition and careful timing of release cuts is required. Crown expansion and subsequent reduction in light levels in the years following the regeneration cut can lead to the elimination of red pine that have successfully established.

7.2.3 Selection System

The selection system is a periodic, partial-cutting system, controlled by basal area, using tree vigour and risk characteristics to determine which trees will be removed. It is more than a reproduction system, since harvesting, regeneration, and tending are carried out simultaneously at each interval, producing an uneven-aged stand. The objective is to produce a representation of all diameter classes (and ultimately, all age-classes) distributed throughout the stand (OMNR 1990).

Features of the selection system:

- well-suited to the management of species that have adapted to grow in small openings in a forest stand
- continual overstory provides a permanent seed source

- growing space is occupied continuously, protecting and stabilizing the soil
- there is permanent vertical closure of the stand (i.e. stand is more windfirm).
- aesthetically pleasing.

Challenges related to the implementation of the selection system:

- high crown closure levels will discourage shade intolerant species. Modifications to the system (e.g. larger canopy openings through group selection) and often site preparation must be carried out to accommodate the maintenance of a component of mid-tolerant species within a stand dominated by shade-tolerant species
- operations are relatively complex, requiring intensive training and supervision
- immediate logging costs are higher than are those for clearcutting
- a strong market is often required for the disproportionate amount of pulp-quality material in early cuts; market conditions may preclude removal of all designated pulp-quality material in harvest cuts
- careful logging practices must be applied in order to limit logging damage to residuals and regeneration.

Variations of the selection system include:

7.2.3.1 Uniform or single-tree selection

Individual trees are cut independently, the growing space being replaced by developing regeneration (of various sizes) that, when thinned over time, will result in replacement of approximately one tree at maturity. This method is exclusive to species that have adaptations to reproduce and grow under a canopy of trees. For example, these tree species (usually maples and beech), must be able to germinate and grow under low light levels, competition from the overstory, and lower microclimatic variation such as temperature and humidity variation. Edge effects are almost non-existent, minimizing availability of browse and understory plant diversity for wildlife, although any cutting will tend to increase browse availability to some extent for short periods of time.

7.2.3.2 Group selection

Trees are removed in small groups of two or more, usually occupying a fraction of a hectare, opening the canopy to a greater degree than single-tree selection. This technique is amenable to regenerating species that can tolerate some level of shade as mature seedlings and saplings such as red spruce and hemlock. The objective is to maintain such species of intermediate shade tolerance in an uneven-aged stand by developing a staged mosaic of even-aged patches regenerated periodically in various cutting cycles. Edges are more clearly defined in this method.

GROWING CONDITIONS CREATED

Application of the selection system provides the environmental conditions required by species adapted to gap-phase replacement, so will largely limit plant regeneration to shade-tolerant species. Thus, either group selection or single-tree selection will have application for red spruce and hemlock, as both have adapted to regenerate and grow under shaded conditions. However, from an operational and wildlife management viewpoint, group selection will be more appropriate.

There are examples of white pine, white cedar and white spruce regenerating in forests under gap phase replacement processes, but except on the least productive of sites, their occurrence is incidental and usually short-lived. Established seedlings of these three species tend to die out under the shade and competition from the overstory (***see*** Carlton *et al.* 1996 for discussion on this issue for red and white pine). Selection management cannot normally be used to establish and recruit white pine, white spruce or white cedar. Note that where localized concentrations of those species occur within stands managed under the selection system, the silvicultural prescription could be modified on a site-specific basis, possibly through the creation of larger openings to create conditions that would favour their continued survival and growth.

7.2.4 Modifications to the Conventional Application of Silvicultural Systems

Clearcut, shelterwood, and selection silvicultural systems have been used in central Ontario for at least 3 decades. Traditionally, these systems have used knowledge of tree species growth and reproductive adaptations (i.e. their silvics) to create conditions that favour the establishment and growth of desired tree species. This focus on individual, commercially, important tree species may not lead to ecological sustainability, as defined by law in Ontario (*Crown Forest Sustainability Act* [RSO 1995]).

Conventional application of silvicultural systems may be inadequate to meet Ontario's goal of producing a variety of forest products while also maintaining productive capacity, site quality, biodiversity and wildlife habitat. Application of conventional silvicultural systems must address new knowledge about the ecology of crop trees and their related systems and processes. This will ensure that silvicultural interventions emulate natural disturbance and create forests with a relatively "natural" composition and structure.

The following modifications to conventional application of silvicultural systems are required:

7.2.4.1 Site and stand protection

Forestry operations differ from natural processes in several important ways. Forestry operations may compact, rut, or erode soil in a manner that does not occur through natural processes. Also, forestry operations may result in damage to residual trees, advance regeneration, and other plant species that may have adapted to survive and recover from natural disturbances. Forestry operations used to implement silvicultural systems must follow guidelines to minimize site and stand damage (***see*** Section 10.4 “Maintenance of Productivity”).

7.2.4.2 Maintenance of wildlife habitat

Conventional application of silvicultural systems produces suitable habitat for a wide range of wildlife species. However, some species have special habitat requirements (e.g. cavity trees, downed woody debris) and practices must be modified to address those habitat needs (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”).

7.2.4.3 Maintenance of structural legacy of the initial forest

Managed forests should have a composition and structure similar to that of naturally-disturbed forests. Stands initiated by natural disturbance usually have some components that remain from the previous forest. This ecological legacy includes important structural components such as downed woody debris (DWD), snags and living cavity trees. Retention of these features is discussed in Section 8.0 “Integrating Timber and Wildlife Habitat Management”.

In pine-dominated forests, fires of low to moderate intensity were the dominant agents of disturbance. A residual overstory comprised of large white pines, red pines or hemlocks, (trees with fire-adaptive traits) generally survived these fires. Data in Day and Carter (1990) suggest that 0 to50 trees per hectare (average of 16 trees per hectare) survived stand initiating fires on 11 study sites in pine forest in the Temagami area. This estimate is based on the number of supercanopy trees remaining in fire origin old growth forests and is thus probably an underestimate.

To ensure silvicultural systems used in the Great Lakes-St. Lawrence conifer forests more closely emulate natural processes, some dominant or codominant white pines, red pines or hemlocks should be retained (when present) in clearcuts and in final shelterwood removal cuts. The number of ‘veterans’ to be retained will vary depending on initial forest conditions and local disturbance regimes. Managers should use locally-relevant information to set targets (e.g. density of supercanopy trees within different forest types based on operational cruise data). In the absence of better local data, managers should refer to the research by Day and Carter (1990). White pines, red pines, or hemlocks retained to provide a seed source (***see*** Section 7.2.1.1 “Seed-tree (clearcut with seed trees)”) or to meet objectives for cavity trees and supercanopy trees (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”) may contribute to targets for veterans.

An example of the importance of the structural legacy:

> The white pine weevil (*Pissoides strobi* (Peck)) is a native insect that is considered an important pest by the forest industry. It has several native vertebrate predators (e.g. black-capped chickadee) and invertebrate predators (e.g. *Lonchea corticis*).

Conventional silvicultural practices favour application of the shelterwood system in pine stands with quick removal of the overstory once regeneration becomes established. Moreover, conventional forest management practices may negatively affect the supply of coarse woody material These conditions may reduce or eliminate the habitat for natural predators of the white pine weevil, leading to an increase in damage to regenerating white pine and a consequent loss of timber production.

By understanding natural disturbance regimes and habitat-predator-prey relationships, a forest manager can modify traditional practices to create conditions that render white pine forest less susceptible to weevil damage. For example, retaining cavity trees, coarse woody debris and a moderate level of residual canopy closure for a fairly long period of time may increase populations of the predators of white pine weevils and consequently suppress weevil damage (Szuba and Pinto 1992).

7.2.4.4 Maintenance of genetic diversity

The Great Lakes-St. Lawrence conifer forest is made up of a limited number of tree species compared to a similar sized area in the tropics. However, it is believed that there is a great deal of population diversity within each species in the Great Lakes-St. Lawrence conifer forests, with the exception of red pine and possibly hemlock (***see*** Section 6.0 “Genetics”). This suggests that isolated populations may be reservoirs of genetic diversity not common elsewhere.

All of the Great Lakes-St. Lawrence conifer tree species have been reduced in abundance across their ecological ranges in Ontario. For example, Gordon (1992) describes the activities that led to declines in hemlock and red spruce, and Aird (1985) and Day and Carter (1990) describe how human activity this century reduced the abundance of white and red pine in Ontario. These reductions fragment existing populations, making it more likely that inbreeding or genetic drift may occur at rates different from those expected if a natural abundance of these species existed today. It is recommended that forest managers use the methods suggested in Section 8.0 “Integrating Timber and Wildlife Habitat Management” to determine levels of restoration for Great Lakes-St. Lawrence conifer species.

Some Great Lakes-St. Lawrence conifers are found in small isolated populations. For example, white pine is found in small populations in its northern range in Ontario. Conventional silvicultural practices may further reduce the number of individuals found in these isolated populations. For example, Buchert *et al*. (1997) found that harvesting many of the white pine capable of breeding from one of the isolated populations in Ontario reduced genetic diversity found in seed produced by residual trees.

Genetic theory suggests that inbreeding depression increases as the probability that relatives will mate increases. Joyce *et al*. *(in press*) suggest the concern with inbreeding diminishes as the effective breeding population increases beyond 50 breeding individuals.

Many factors affect an individual tree's ability to breed. For example, all trees do not flower or become receptive at the same time. An effective breeding population will be at least 50 sexually mature individuals in close enough proximity that they are able to exchange pollen. Based on population theory it is widely recommended that, if available, enough dominant and codominant white pine, red pine or hemlock trees be retained after harvesting to maintain the genetic integrity and reproductive success of the residual population.

Determining stand isolation from pollen is not easy. Pollen dynamics are affected by population size, position of trees on the landscape and wind to name a few factors (Di-Giovanni and Kevan 1991). Di-Giovanni and Kevan (1991) report on studies that show most pollen falls within 20 m to 1,000 m of the parent tree. However, pollen is also known to be carried for many kilometers by turbulent winds.

Rules of thumb:

- Retain a population of at least 100 mature individuals capable of breeding to be used as a minimum to ensure an effective breeding population.

- Consider a stand to be isolated if it is more than 1 km from another similar stand.

Due to the great diversity in conditions that exists in forests, the minimum number of individuals and their distance to other populations of similar species should be used as general rules-of-thumb. They should be used or modified after consultation with experts on tree genetics.

It is recommended that isolated populations of white pine, red spruce and hemlock with fewer than 100 individuals be harvested only if:

- the area is already satisfactorily regenerated, or

- seed from the appropriate seed zone is available and is used to regenerate an equivalent site within the seed zone, or

- regeneration must be secured before the removal of mature breeding individuals. This may be achieved using pre-harvest site preparation.

Artificial regeneration may result in the transfer of seed or seedling stock over large distances. This practice can result in the introduction of new genetic material from populations not adapted to local conditions into locally-adapted populations. Joyce *et al. (in press*) recommend seed and seedling used in regeneration follow Ontario's system of seed zones and seed transfer guidelines.

7.2.5 Recommendations for the selection and implementation of silvicultural systems based on ecosites and target species

Ecosites are usually complexes with a variety of tree species associations. A forest manager must be able to understand and create conditions suitable for a number of tree species. Therefore, the following discussion will deal with associations of species and a variety of objectives. Silvicultural practices described in the following sub-sections (and also Section 7.3 “Site Preparation”, Section 7.4 “Renewal” and Section 7.5 “Stand Maintenance”) are summarized in Appendix E “Silvicultural Options Tables”. These tables are presented for quick reference and do not contain all of the information needed to develop silvicultural ground rules or forest operations prescriptions. Authors of Forest Management Plans and site-specific prescriptions are advised to read the text to obtain all of the information required to perform their duties.

7.2.5.1 Desired tree species - white pine

	POSSIBLE ECOSITES - White pine
Central Ontario	11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30
Northwest Ontario	11, 15, 18, 24
Northeast Ontario	1, 6b, 6c, 7b, 15

Uniform shelterwood is generally the silvicultural system of choice for the management of white pine where an overstory exists. However, sufficient conifer of acceptable species (or hardwood with complimentary site and light requirements) must be present so that a post-cut condition approximating the target crown closure level can be attained. Because an irregular distribution of conifer is often encountered within stands of the Great Lakes-St. Lawrence forest region and white pine within the canopy can be improperly classified, the Forest Resource Inventory can only provide an approximation of the likely silvicultural system. A pre-harvest assessment may be required for confirmation. This is especially true for stands appearing to be in a mixedwood condition (i.e. 30 to 50 per cent pine according to the Forest Resource Inventory).

Basal area is one measure which will assist in determining suitability of a stand or areas within a stand for which shelterwood management is appropriate. Stands with a basal area greater than 12 m^2/ha of white pine *and a lesser component of red pine, white spruce, hemlock or red oak*, will provide approximately 50 per cent crown closure of acceptable species following a regeneration cut, and should be managed under the shelterwood system. However, basal area is not a good indicator of canopy closure from stand to stand with trees of various diameters and densities, and should not be used as the sole criteria when implementing the uniform shelterwood system.
A four cut shelterwood is usually used in stands that have at least 50 per cent white pine and red pine, are well stocked (over 70 per cent) and where the proportion of white pine is greater than red pine. A two or three cut shelterwood may be used when white and red pine compose at least 30 per cent of the stand.

It is recommended that concentrations of white pine within a stand be managed using the uniform shelterwood system.

Pre-harvest or post-harvest treatments may be required to ensure adequately stocked stands of white pine. (*See* Section 7.3 “Site Preparation”, Section 7.4 “Renewal” and Section 7.5 “Stand Maintenance”).

Non-forested sites may be artificially regenerated to white pine on sites with climatic and soil conditions similar to those found on ecosites described above. Plantation-grown white pine may have poor form and branching habit and can have poor growth compared to other tree species. To improve the quality and growth of white pine it may be necessary to grow it as a mixture with intolerant hardwoods, red oak, and/or other pines or at higher densities.

Uniform Shelterwood System

The uniform shelterwood silvicultural system is the preferred system for harvesting and regenerating white pine. *Unlike the classic shelterwood systems described in forestry textbooks, the uniform shelterwood system described here has been developed to more closely match the conditions created by natural stand initiating disturbances in white pine stands in Ontario*. For example, classic shelterwood systems usually require the removal of the overstory shortly after regeneration has been established. The system described here requires the retention of some of the overstory for many years after regeneration has been established.

Preparatory Cut

The preparatory cut is designed to develop thrifty seed-bearers and to remove undesirable species or individuals from the canopy. The treatment is normally scheduled in stands which are in the 61 to 80 year age-class, but more important than age alone, is the current degree of crown development. Young stands, or stands which are overstocked, may not have developed crowns large enough to allow adequate seed production and distribution. Where crown diameter is in the 4 to 5 metre range, preparatory cutting is appropriate.

Procedure:

- identify and retain dominant and codominant trees of good form and vigour, uniformly distributed throughout the stand.

- favour white pine in the residual stand while recognizing the importance of other species and their contribution to forest biodiversity objectives (***see*** TABLE 10.0.1 in Section 10.0 “Management Standards”). Where white pine is unavailable, good quality stems of other species can be maintained to ensure full utilization of the site.

- space to allow for adequate crown development of residual trees.

Rules of thumb:

  - full crown spacing between residuals (branch tip to branch tip), or

  - spacing between residual stems equal to 30 per cent of average stand height may result in achieving the desired 50 per cent crown closure.

- protect regeneration present at the time of the preparatory cut during the logging operation, but recognize that regeneration will occur during the next stand entry (regeneration cut).

- follow recommendations in Section 8.0 “Integrating Timber and Wildlife Habitat Management” to maintain wildlife habitat.

Regeneration (Seed) Cut

The regeneration cut is specifically designed to facilitate natural or artificial regeneration. The regeneration cut is usually applied either in stands that are 81 to 100 years of age, or about 20 years after a preparatory cut has been made, or at an older age if no previous regeneration cut has been successfully completed. In order to contribute to regeneration targets tree crowns should have a diameter of at least 6 to 8 metres.

Procedure:

- retain dominant and codominant white pine while recognizing the importance of other species and their contribution to forest biodiversity objectives. Hardwoods may be retained where necessary to fill canopy gaps, but only when suitable Great Lakes-St. Lawrence conifers are not available.

- thin from *below* and concentrate on removing the most defective and least vigorous trees, leaving better-quality trees for seed, site protection, and high-quality and volume wood production.

- favour the retention of trees with full, symmetrical crowns, good form, and no evidence of serious disease or insect susceptibility.

- reduce crown density to 40-50 per cent crown closure. At this point, white pine seedling height growth is near the optimum level (Logan 1959), but diameter and volume growth will be substantially less than that achieved in full sunlight.

- Rules of thumb:

  - 1/2 crown spacing or spacing trees to 40 per cent of their height may result in achieving the desired 40-50 per cent crown closure.

- where it is desired to maintain a red oak/white pine mixture, (e.g. ES 14.1, 14.2), crown closure is reduced to 40 per cent.

- for higher levels of natural regeneration time the regeneration cut, where possible, to coincide with a good seed year. Ideally schedule site preparation during a good seed year.

- follow recommendations in Section 8.0 “Integrating Timber and Wildlife Habitat Management” to maintain wildlife habitat.

- site preparation or artificial regeneration may be required to satisfactorily regenerate the area.

Removal Cut

Removal cuts are scheduled to follow the successful establishment of regeneration. The timing and number of individual cuts depend on the length of the establishment period, growth and vigour of established regeneration, usually 30 cm to 1.5 m in height, growth and value appreciation of shelter trees, and the need to moderate the impact of white pine weevil.

There are usually two removal cuts (a release cut, followed by a final removal cut) as follows, however, in some circumstances, a single removal cut may be appropriate:

Release Cut

Procedure:

- retain 30-40 per cent crown closure (usually full crown spacing between residual trees) during the release cut to provide adequate protection to the regeneration from white pine weevil.

- favour best quality residuals to maximize future growth and value increment of the overstory.

- apply minimum-damage logging techniques in felling and skidding operations (***see*** Section 9.0 “Harvesting Considerations”).

- follow recommendations in Section 8.0 “Integrating Timber and Wildlife Habitat Management” to maintain wildlife habitat.

Final Removal

Procedure:

- maintain overstory until regeneration achieves a total height of 5-6 metres.

- apply minimum-damage logging techniques in felling and skidding operations.

- maintain desired number of dominant or codominant white pine, red pine or hemlock veteran trees per hectare. ***See*** Section 7.2.4 “Modifications to Conventional Silvicultural Systems” for rationale.

- follow recommendations in Section 8.0 “Integrating Timber and Wildlife Habitat Management” to maintain wildlife habitat.

Single Removal Cut

Procedure:

- a single removal cut may be used if regeneration has: a) reached a mean height of 1.5 m, b) there is little risk of subsequent white pine weevil damage, c) a minimum of 1,000 residual seedlings per hectare will remain uniformly distributed over the site after the final removal cut is made, and d) residuals are not required for other purposes.

- remove the overstory in a single operation while maintaining desired veterans (*see* Section 7.2.4 “Modifications to Conventional Silvicultural Systems”), follow careful logging practices (***see*** Section 9.0 “Harvesting Considerations”), and maintain wildlife habitat (Section 8.0 “Integrating Timber and Wildlife Habitat Management”). This early release treatment is the best way to achieve rapid volume production of regenerated white pine (Lancaster 1984).

Strip Shelterwood System

This system has had limited use in Ontario. The most common application of the system involves clearcutting very narrow strips. The adjacent uncut stand provides side shade.

Procedure:

- narrow strips usually no wider than half the height of the stand
- established regeneration can be protected by avoiding cut areas during subsequent operations
- for higher levels of natural regeneration time the cut, where possible, to coincide with a good seed year. Ideally schedule site preparation during a good seed year
- maintain desired number of veterans (***see*** Section 7.2.4 “Modifications to Conventional Silvicultural Systems”)
- follow recommendations in Section 8.0 “Integrating Timber and Wildlife Habitat Management”.

Clearcut System

The clearcut silvicultural system may be used to restore white pine to appropriate sites or maintain it at current low levels of abundance. Restoration of white pine will usually occur on central Ontario ES 17.1, 18.1, 19.1, 30.1 as well as on Northeast ST 6b, 6c. These ecosites usually have low levels of white pine and high levels of intolerant hardwoods and boreal conifers growing on soil conditions that will allow white pine to establish and grow. Understory vegetation management is critical, as the site will be quickly occupied by regenerating intolerant hardwoods and residual tree species that may not be harvested, such as balsam fir and red maple.

Clearcut with Seed Trees (white pine/poplar/white birch mixedwood)

Stands having significant hardwood representation, but with a component of white pine, red pine, white spruce or hemlock are typically managed to maintain or enhance that conifer component. Where this is the management objective, and the conifer component has a basal area of 4 to 12 m^2/ha , a clearcut with seed trees approach is usually acceptable. This system may also be used when it is desired to regenerate jack pine together with a component of red and white pine, for example in central Ontario ES 13.

Application of this system has generally required retention of 10 to 35 white pine trees per hectare, well-distributed across the site. The intent, however, is to retain sufficient trees of the proper quality and seed-producing capability to provide seed to regenerate the stand, and not to simply meet a target of a minimum number of seed-trees per hectare. The forest manager must therefore consider such factors as: 1) the amount of seed produced per tree, 2) prospective survival of the trees, and 3) the number of seeds required to yield an established seedling under the prevailing seedbed conditions (Smith 1986).

Artificial regeneration treatments following harvest may be needed to ensure minimum stocking and density of white pine. (***See*** Section 7.3 “Site Preparation”, Section 7.4 “Renewal” and Section 7.5 “Stand Maintenance”).

Procedure:

- individuals selected for retention as seed trees must be windfirm, and capable of producing viable seed. Tree-markers will therefore select trees to be retained using the following guidelines:
    - retain individuals in the dominant or codominant crown class.
    - retain individuals with wide, deep crowns, and relatively large live crown ratios, and diameter/height ratios of less than 1:80.
    - suppressed trees with weak feathery crowns will not produce sufficient seed to meet regeneration targets.

- use caution in retaining species that are prone to windthrow (white spruce may be retained to augment diversity within a red or white pine stand seed tree cut, and may produce seed and offspring in the short term, but recognize that individuals may have low long-term survivability).

- select seed trees that are old enough to produce abundant fertile seed (optimum seed bearing age for both white and red pine is from 50 to 150 years).

- favour individuals that have produced seed in the past. Previous seed production capability may indicate future seed production capability.

- attempt to confine choices to the best phenotypes. Within specific areas of the operating block where good phenotypes are not available, retain individuals which have developed imperfectly due to environmental influences that have operated at random.

- apply minimum-damage logging techniques in felling and skidding operations. Retain desired veterans (***see*** Section 7.2.4 "Modifications to Conventional Silvicultural Systems" for rationale).

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 "Integrating Timber and Wildlife Habitat Management").

Clearcut with Standards

Standards are trees that are retained for a variety of purposes, such as attempting to meet ecological objectives by retaining veterans.

This system is appropriate where white pine is to be maintained or restored to higher stocking and density levels than found in the current stand. It is recommended for use in stands that have 4 m^2/ha basal area of white pine or less. It may also be used where a mixture of jack pine together with a small amount of red and white pine are desired.

Procedure:

- the overstory is removed in one harvest operation with consideration for the factors described in Section 7.4.2 "Modifications to Conventional Silvicultural Systems".

- pre-harvest or post-harvest regeneration treatments may be required if minimum stocking and density targets for the pines are to be achieved. (***See*** Section 7.3 "Site Preparation", Section 7.4 "Renewal" and Section 7.5 "Stand Maintenance").

7.2.5.2 Desired tree species - red pine

	POSSIBLE ECOSITES - Red pine
Central Ontario	11, 12, 13, 17.1, 18.1, 19.1, 20
Northwest Ontario	11, 15, 18, 24
Northeast Ontario	1, 2a, 2b, 3b, 6a, 6b, 7b, 15

Red pine will germinate under partial shade but requires high levels of light for continued growth. It is an infrequent seed producer in Ontario. Its environmental requirements for establishment and growth, and lack of seed crops have made natural regeneration of red pine quite rare in some areas.

For natural regeneration red pine may be managed under the shelterwood system. Artificial regeneration may be used where clearcut systems are chosen.

Non-forested sites may be artificially regenerated to red pine when climatic and soil conditions are similar to those found on ecosites described above. Red pine grown in plantations have excellent growth and produce good quality stems.

Uniform Shelterwood System

Uniform shelterwood is an option when dealing with mixtures of white and red pine or pure stands of red pine. However, unless there is prompt release of established red pine regeneration from the overstory and understory, more shade-tolerant species (white pine, white spruce, red maple, balsam fir) will dominate, and the red pine regeneration will disappear.

Red pine growing within white pine stands should be marked and harvested using the procedures described in this section. Marking and harvesting methods described in this guide for white pine should be used for patches of white pine.

Preparatory Cut

Thinned stands may already have fully developed crowns, in this case a preparatory cut is not necessary. Dense stands will have to be thinned to allow for full crown development. The preparatory cut would follow the same procedures and intensity of harvest as a white pine stand. ***See*** procedures described under white pine preparatory cut.

Regeneration (Seed) Cut

Procedure:

- thin from *below* and concentrate on removing the most defective and least vigorous trees, leaving better-quality trees for seed, site protection, and high-quality and volume wood production.

- favour the retention of trees with full, symmetrical crowns, good form, and no evidence of serious disease or insect damage. Retain dominant and codominant red pine. Retention of secondary associates will be according to the priority listing (***see*** TABLE 10.0.1 in Section 10.0 “Management Standards”).

- reduce canopy density to about 35 per cent crown closure.

- Rule of thumb:

    - full crown spacing

- time the regeneration cut, where possible, to coincide with a good seed year. Ideally schedule follow-up site preparation or supplementary tending, where necessary, during subsequent good seed years.

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”).

- apply minimum-damage logging techniques in felling and skidding operations.

Removal Cut

Procedure:

- the removal cut may occur once the regeneration stocking and density targets have been met and seedlings are at least 1 m in height.

- overstory removal should be modified to retain the desired number of veterans as described in Section 7.2.4.3 “Maintenance of the Structural Legacy of the Initial Forest”.

- careful logging techniques must be used to minimize damage to regeneration.

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”).

Clearcut System

The clearcut silvicultural system may be used to restore red pine to appropriate sites. It may also be used to maintain red pine in stands with high numbers of other species. Restoration of red pine will usually occur on central Ontario ES 17.1, and on Northeast ST 2a, 2b, 3b, 6b, 6c. These ecosites usually have low levels of red pine and high levels of intolerant hardwoods and boreal conifers growing on soil conditions that will allow red pine to establish and grow. Understory vegetation management is critical, as the site will be quickly occupied by regenerating intolerant hardwoods and residual tree species that may not be harvested such as balsam fir and red maple.

Clearcut with Seed Trees or Standards

These systems are appropriate where red pine abundance is to be maintained or restored to higher stocking and density levels than found in the current stand.

Procedure:

- the overstory is removed in one harvest operation with consideration for the factors described in Section 7.2.4 "Modifications to Conventional Silvicultural Systems". The procedure used to select and retain white pine seed trees is also used to select and retain red pine seed trees.

- space seed trees one tree length apart where available.

- pre-harvest or post-harvest regeneration treatments may be required if minimum stocking and density targets for red pine are to be achieved. (***See*** Section 7.3 "Site Preparation", Section 7.4 "Renewal" and Section 7.5 "Stand Maintenance").

Strip Clearcut

Dense stands of red pine may be difficult to harvest using the uniform shelterwood system for red pine. Logging damage may be high, and residual trees prone to wind-throw.

Procedure:

- narrow strips, usually one tree length in width, may be cut into the stand.

- cut strips are progressive or alternate.

- the cleared area is regenerated naturally or artificially using the post harvest treatments describe in Section 7.3 "Site Preparation", Section 7.4 "Renewal" and Section 7.5 "Stand Maintenance".

- protect established regeneration from mechanical damage during harvest and regeneration operations.

- overstory removal should be modified to retain the desired number of veterans as described in Section 7.2.4.3 "Maintenance of the Structural Legacy of the Initial Forest".

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 "Integrating Timber and Wildlife Habitat Management").

7.2.5.3 Desired tree species - hemlock

	POSSIBLE ECOSITES - Hemlock
Central Ontario	28, 30
Northwest Ontario	
Northeast Ontario	

Hemlock is shade-tolerant, and well-adapted to establishing itself in gaps created by wind events. However, its growth is limited by high levels of shade, needing more light if seedlings are to form a new stand.

Hemlock seedlings and saplings are preferred browse for white-tailed deer and moose. As a result recruitment of hemlock seedlings less than 3 m in height will be limited when deer and moose populations are high. Silvicultural practices must consider the effect of deer and moose browsing on regenerating hemlock. Harvest and hemlock regeneration treatments may not be possible where it is important to maintain high deer or moose herds and wintering areas are limited.

Selection System

Group Selection

Group selection may be used in areas where a mosaic of ages and sizes of trees are desired within an operating block. It may also be used in stands that are important to deer and moose, but where hemlock regeneration is not required. In these stands, red spruce, a species not usually browsed by deer and moose can be planted.

Procedure:

- the maximum size of group openings is equal to the height of the stand (usually 20 to 30 m).

- group openings are uniformly distributed over the cut block.

- group openings cover not more than 20 per cent of the block during each cut.

- at least 60 per cent of the stand must be over 10 m in height if the stand is important to deer and moose and may be regenerated with red spruce.

- the return cycle between each cut is 20 years.

- log in the summer to create soil disturbance which favours hemlock germination.

- retain veterans (***see*** Section 7.2.4 “Modifications to Conventional Silvicultural Systems” for rationale).

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”).

Uniform Shelterwood

The uniform shelterwood silvicultural system is recommended for use where moose and deer populations are not high enough to prevent recruitment of hemlock seedlings. Where moose or deer browsing may prevent recruitment of hemlock seedlings, management strategies must be developed in the Forest Management Plan.

Procedure:

- a three-cut shelterwood is recommended.

- the regeneration cut reduces crown closure to 60 to 70 per cent.

- the first removal occurs when regeneration meets at least the minimum standards and is between 30 cm and 1 m in height.

- maintain 40 to50 per cent crown closure after the first removal cut.

- the final removal may occur when seedlings are over 1 m in height.

- retain dominant and codominant hemlock while recognizing the importance of other species and their contribution to forest biodiversity objectives. Hardwoods are usually targeted for removal.

- retain veterans; apply Section 7.2.4.3 “Maintenance of Structural Legacy of the Initial Forest”.

- follow recommendations to maintain wildlife habitat (***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management”).

- careful logging practices are used during each harvest.

7.2.5.4 Desired tree species - white spruce

	POSSIBLE ECOSITES - White spruce
Central Ontario	17.2, 18, 19, 20, 22, 33
Northwest Ontario	
Northeast Ontario	3b, 6b, 6c

Because white spruce rarely forms pure stands, decision processes related to the management of the species usually involve consideration of the silvical requirements of its associates. White spruce is very similar to white pine in terms of light and seedbed requirements and when managed in such stands according to the uniform shelterwood procedures already described, is likely to regenerate naturally, establish itself in association with white pine regeneration and continue to develop.

White spruce is also commonly associated with the less tolerant trembling aspen or white birch (central Ontario ES 11b, 12a ,12b, 13a ,13b, 21a, 21b, and Northeast ST 3b, 6b, 6c). Depending on the stand objective, and on the dominance of white spruce within the stand, the manager can choose to clearcut and regenerate artificially, or apply a uniform shelterwood approach.

Uniform Shelterwood System

Procedure:

- retain dominant and codominant spruce while recognizing the importance of other species and their contribution to forest biodiversity objectives.

Clearcut Systems

Procedure:

- ***see*** procedures described for white pine.

7.2.5.5 Desired tree species - red spruce

	POSSIBLE ECOSITES - Red spruce
Central Ontario	30, 32
Northwest Ontario	
Northeast Ontario	

Red spruce is able to establish and grow under shade. It requires some soil disturbance to germinate and survive as a young seedling.

It is not a preferred browse species for ungulates, such as deer and moose. It may be introduced into stands of hemlock that are important for maintaining ungulate populations at levels that affect recruitment of hemlock.

Red spruce has been severely reduced across its ecological range in Ontario. Forest workers must be able to identify this species to limit further losses in its population. Tree-markers must mark to retain red spruce during tree-marking operations in the conifer and tolerant hardwood Great Lakes-St. Lawrence forest.

Red spruce growing in open conditions is particularly prone to winter drying and windthrow. It can be regenerated by using selection or shelterwood silvicultural systems.

Selection System

Procedure:

- red spruce growing in association with tolerant hardwoods can be grown using single-tree selection. ***See*** "*A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario"* for details on how to implement single tree selection.

- ideally harvest should be done in the frost-free season so that the humus layer can be exposed. The litter and fibric layers dry rapidly and act as a physical barrier, limiting germination of red spruce. If harvest operations do not create desired seedbed conditions, site preparation will be required.

- red spruce may also be maintained or introduced into a stand using the group selection system. The procedures described for hemlock can be used for red spruce.

- retain dominant and codominant spruce while recognizing the importance of other species and their contribution to forest biodiversity objectives.

Uniform Shelterwood System

Procedure:

- red spruce growing in association with hemlock or other spruces can be maintained through the use of the uniform shelterwood system. Red spruce may also be introduced into stands where it is not currently present through the use of the uniform shelterwood system. The procedures described for hemlock can be used for red spruce. Retain dominant and codominant spruce while recognizing the importance of other species and their contribution to forest biodiversity objectives. Favour the removal of balsam fir, which is quite abundant in central Ontario ES 30.1, 30.2, and 32.

- because of its shallow root system, no more than 25 per cent to 33 per cent of the overstory basal area should be removed in a partial cut (Blum 1991).

- where advanced regeneration is lacking, employ shelterwood approach. Remove 33 per cent to 50 per cent of basal area in two or more harvests. Where windthrow is a hazard, do not remove more than 33 per cent of the basal area in one cut.

7.2.5.6 Desired tree species - white cedar

	POSSIBLE ECOSITES - White cedar
Central Ontario	21, 22, 32, 33
Northwest Ontario	17, 37
Northeast Ontario	13

White cedar grows in a variety of stand conditions. It is found in the understory of most Great Lakes-St. Lawrence stands except for those dominated by red pine and jack pine on nutrient poor, shallow or dry sites.

Like hemlock, white cedar is a preferred browse for deer and moose. If deer populations are high, cedar recruitment will be limited. If cedar stands are important to maintaining a desired population of deer and that population level affects cedar recruitment, harvest and regeneration activities may not be possible.

White cedar requires humid conditions for germination and early growth. This makes it necessary to protect the site from excessive dry spells during the growing season during the establishment phase of white cedar. A number of silvicultural systems can be used to create the conditions that will maintain or allow the introduction of cedar into stands, provided deer populations are low.

Selection System

Group Selection

Procedure:

- use the procedures described for hemlock.

Uniform Shelterwood System

Procedure:

- use the procedures described for hemlock.

Clearcut System

Strip and Patch Clearcut

Procedure:

- use narrow (20 m wide) strips or patches.
- larger patches (16 to 65 ha in size) may be cut to reduce deer browse damage.
- last set of strips and patches cut using a two cut shelterwood system once first cut areas have successfully regenerated and seedlings are at least 1 m in height (Johnson and Booker 1983).

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7.3 Site Preparation

7.3 Site Preparation

by Andrée E. Morneault

Site preparation refers to treatments that are planned and conducted to prepare a site for natural or artificial regeneration. The 3 major types of site preparation, mechanical, chemical, and prescribed burning, can be used alone or in combination.

The purpose of site preparation is to create conditions suitable for natural or artificial regeneration by achieving one or more of the following objectives:

- control competing vegetation (Sutton 1985)
- create suitable conditions for the germination, establishment, and growth of natural regeneration (***see*** Sections 3.4 “Silvics of the Great Lakes-St. Lawrence Conifers” and 7.2 “Silvicultural Systems”) and/or the planting, establishment and growth of artificial regeneration (***see*** Section 7.4 “Renewal”) (Sutton 1985; Kennedy 1988; Sutherland and Foreman 1995)
- redistribute, align and in some cases, to remove slash (Sutton 1985)
- facilitate regeneration and subsequent tending operations, to improve planting quality, and to reduce establishment costs (Sutton 1985).

These objectives will be affected either positively or negatively by site conditions and the choice of site preparation method.

The choice of site preparation treatment will depend on the silvicultural objectives for the site and the site conditions. This implies a knowledge of the ecology of both the crop trees and the other vegetation on the site and of the different site preparation options that are available. Site conditions such as terrain, exposure, soil type, erosion hazard, size of treatment area, and accessibility can also influence the choice of site preparation method. Some questions that should be asked are: Will natural or artificial regeneration be used or a combination of both? Will selection, shelterwood or clearcut silvicultural systems be used? What are the main competing species and how will they respond to the treatment? What is the autecology of the crop species? Is the site nutrient-rich or nutrient-poor? What is the topography? The choice of site preparation treatment also depends on the time, labour, equipment, materials and money that are available and on any restrictions imposed by law or policy (Sutton 1985).

Site preparation can be done either pre-harvest or post-harvest. Pre-harvest treatments can be very effective on sites targeted for natural regeneration and can be done using mechanical equipment, herbicide application (Rudolf and Watt 1956), and/or prescribed fire (Van Wagner 1993; McRae *et al*. 1994). The competing vegetation can be controlled by both the treatment and the shaded environment under the canopy of the overstory, the seedbed can be prepared, and the new crop can be established before the harvesting takes place. Ideally, site preparation should be completed in a good seed year.

However, the seedbed may remain receptive for 2 or 3 years, unless there is a large hardwood component in the overstory or understory. It is best to wait at least 3 years after seed germination to do the harvesting treatment and to harvest after snow-fall to avoid damaging the newly established seedlings. Securing natural regeneration before harvest is an ideal way of maintaining the genetic potential of a stand (***see*** Section 7.2.4 “Modifications to Conventional Silvicultural Systems”).

Timing post-harvest site preparation with a good seed year is more critical where natural regeneration is required. Competing vegetation quickly invades most sites disturbed by logging. If the site is to be planted, site preparation should occur as soon as possible after harvesting and trees should be planted as soon as possible after site preparation is completed.

Mechanical, chemical, and prescribed burn treatments can be applied singly or in combination depending on site conditions. On ecosites with high cover of hardwood shrubs and trees in the understory, a combination of mechanical/chemical or prescribed fire/chemical treatments may be necessary to provide adequate competition control and good conditions for seedling establishment and growth. A reduction in the abundance and vigour of competing vegetation during the critical establishment period is essential in managing vegetation communities to favour mid-tolerant to intolerant conifer species.

Mechanical/chemical treatments can be done consecutively or simultaneously. Mechanical site preparation can be followed by root-contact herbicides such as *hexazinone* or *simazine*. The mechanical treatment removes surface vegetation and/or exposes mineral soil which facilitates the follow-up chemical treatment by allowing more chemical to reach the soil surface (Desrochers and Dunnigan 1991). A delay between the site preparation treatment and the herbicide application is recommended, because soil-active herbicides are usually most effective when applied when the soil has settled and a stable surface is available (Campbell 1981).

A common treatment regime used in white pine stands in Ontario is a mechanical treatment followed by a foliar herbicide application. Maximum vegetation control is obtained when the herbicide treatment is delayed for approximately 1 growing season after the mechanical treatment to allow time for re-growth of the vegetation and growth of any dormant seed-bank or seed-rain species (Campbell 1981).

In some cases, chemical treatments are done before the mechanical treatment. Herbicides are applied when the target vegetation is growing vigorously (July-early August) so it is quickly translocated and effectively kills target plants before the mechanical treatment is applied in the fall. Existing vegetation will be controlled, but the site may be invaded by species that reproduce by wind-borne seed or seeds in the seedbank. This combination of treatments has been effective in creating conditions for natural white pine regeneration on land managed by Menominee Tribal Enterprises in Wisconsin (personal observation).

Combining mechanical and chemical site preparation in one operation can be done using equipment like the Bräcke herbicider and has the following advantages:

- reduced treatment costs compared with two separate operations

- shortened delay between harvesting and reforestation because only one event needs to be scheduled (Alm and Long 1988)

- reduced chemical usage because spray nozzle is directed to the targeted vegetation (Desrochers and Dunnigan 1991).

However, the disadvantages are:

- the treatment window is reduced

- less control of vegetation because the herbicide is not applied at the time when it is most effective.

Mechanical and chemical site preparation can also be used before a prescribed fire. Mechanical site preparation can be conducted prior to prescribed fire to tramp dead or dying vegetation on a site to improve fuel conditions prior to burning (McRae 1986). A herbicide application can also be applied before a prescribed burn to create more fuel and prevent poor fire spread by reducing the amount of green vegetation on a site before the burn. An additional benefit is the control of competing vegetation, so that it does not sprout and sucker after the fire.

7.3.1 Mechanical Site Preparation

Mechanical site preparation uses a variety of different equipment ranging from logging equipment to tractors and bulldozers with various types of blades, disks, or chains. This equipment is used to shear, disk, furrow, terrace, trench, strip, rip, punch, slit, drag, chop, till, churn, mix, or crush the ground and vegetation (Steward 1978). In addition to providing initial vegetation control, mechanical treatments also manage slash and facilitate subsequent regeneration operations (Carter *et al.* 1978). Small tractors and bulldozers with blade rakes and 6- way blades are often used in the Great Lakes-St. Lawrence forest conifer sites managed using the uniform shelterwood system. On areas managed using the seed tree or clearcut system, a wider variety of machinery is used such as Bräcke scarifiers, disk trenchers, and larger tractors with blades and rakes.

Appropriate use of mechanical treatments can create suitable conditions for the establishment and growth of natural and artificial regeneration (TABLE 7.3.1). The two most important site conditions affected by mechanical site preparation are soil moisture availability and soil temperature. Mechanical site preparation can increase soil moisture availability and thus promote seed germination and seedling root growth and function. Warming the forest floor by scarifying a site has positive effects on nutrient availability by promoting organic nitrogen mineralization in the humus layer, decomposing slash, enhancing ectomycorrhizal fungi growth, and promoting tree root growth (Örlander *et al.* 1990). Increases in soil temperature can favour seedling height growth and possibly early root growth in the first and second year after planting (Brand and Janas 1988). This effect becomes less important in the second year, when brush control becomes necessary to increase diameter growth (Brand 1990).

TABLE 7.3.1: Selected microsite condition created by mechanical site preparation		
SITE MODIFICATION	EFFECT ON MICROSITE	REFERENCE
Remove litter layer	Increase moisture available for germinating seeds.	Sutherland and Foreman (1995)
	Increase soil temperature.	Brand (1990)
Mix mineral soil and organic layer	Increase soil moisture holding capacity in seedling rooting zone.	Morris and Lowery (1988), Grossnickle and Heikurinen (1989), Stathers and Spittlehouse (1990)
	Increase soil temperature by reducing soil bulk density and improving drainage and aeration.	Thomson and McMinn (1989), Stathers and Spittlehouse (1990)
Create depressions	On dry or exposed sites, can improve moisture availability for seedlings.	McMinn and Hedin (1990), Örlander *et al.* (1990)
Remove vegetation	Increase soil temperature.	McMinn and Hedin (1990), Spittlehouse and Stathers (1990)
	Conserve moisture in seedling rooting zone.	Spittlehouse and Childs (1990)
Mound or plow	Increase soil temperature in seedling rooting zone.	McMinn and Hedin (1990)

The response of competing vegetation to mechanical disturbance depends on the reproductive characteristics of the species and the depth or location of the parent root systems (***see*** Section 3.4.7 "Autecology of Associated Species"). Information on the response of various species of vegetation to mechanical site preparation in the Great Lakes-St. Lawrence forest is scarce. However, Sutherland and Foreman (1995) have attempted to predict the response of vegetation to various mechanically produced microsite categories based on both the reproductive method and rooting depth of common non-crop vegetation species (TABLE 7.3.2)

TABLE 7.3.2: Forest floor modifications as a result of mechanical scarification and the influence of microsite categories on site factors (reproduced with permission ***from***: Sutherland and Forman 1995)

Microsite description	Vegetative reproduction			Sexual reproduction	
Effect on competing vegetation: + = promotes (++ = strongly); 0 = no effect; – = discourages (– – = strongly). Legend: mineral; organic	from shoots	from roots		wind-borne	seed bank
	(e.g., *Acer, Alnus, Betula, Cornus, Ledum, Corylus, Salix*)	in organic layer (e.g., graminoids, *Vaccinium*)	in mineral soil (e.g., *Populus, Rosa, Rubus, Salix*)	seed (e.g., graminoids, *Betula, Epilobium, Populus*)	(e.g., *Cornus, Prunus, Rosa, Rubus, Vaccinium*)
All soils					
Undisturbed mature stand	0	0	0	0	0
Upland mineral soils					
Overstory removed, organic and mineral layers undisturbed (e.g., cutover)	++	+	+	0 to +[a]	+
L layer and part of F layer removed or displaced (e.g., shallow screef)	+	+	+	+	++
LFH removed, mineral soil intact (e.g., screef)	– – to –[b]	–	++	++	–
LFH removed, some mineral soil removed (e.g., deep screef)	– –	– –	– – to –[c]	++	– –
LFH removed, mineral mound on mineral soil	– –	– –	– – to –[d]	+	– –
LFH and mineral layers inverted (mineral mound on organic layer)	+ to ++	– to +[e]	– to +	+	– to +[f]
LFH and mineral mixed (e.g., tilling)[g]	– to +	– to +	– to +	++	++
Lowland organic soils[h]					
Part of Of removed (e.g., shearblading)	–[i]	– to +[j]	not applicable	+	+
Drainage of layer (e.g., ditching)	+	+	not applicable	0	+

[a] Will promote if organic layer is shallow and/or moist.
[b] Control of sprouting is improved for species that tend to root in the organic layer.
[c] Control of sprouting depends on removal of root systems.
[d] Control depends on removal of root systems below ground and mineral mound sufficiently deep to suppress sprouting.
[e] Control of sprouting increases with increased depth of capping.
[f] A thin cap of mineral soil tends to encourage germination of seeds in the organic layer; a thick cap discourages germination.
[g] Control depends on degree of mix: fine mixing (e.g., rototilling) discourages, coarse mixing (e.g., single-pass discing) encourages.
[h] Of, Om, and Oh represent fibric, mesic, and humic organic horizons, respectively.
[i] Will promote *Ledum* and *Vaccinium* species.
[j] Control depends on degree of removal of root systems and stimulation of residuals.

The effectiveness of mechanical site preparation in controlling competing vegetation will depend on the area disturbed, the severity of the disturbance, and the delay between site preparation and seeding or planting. The effect of mechanical site preparation on vegetation can be categorized in terms of the depth and area of treatment (adapted from Delong 1989) as follows:

- Removal of surface vegetation: trees and shrubs are pushed aside or sheared off, but some low shrubs, herbs, and most of the humus are left intact. Thus there is little change in the floristic composition, but their height and cover are reduced.

- Removal of top layer of forest floor (L and F layer of duff): damages but does not remove understory hardwood tree and shrub roots from soil, thus stimulating sprouting and suckering. Secondary treatments may be necessary to contain sprouting plants (Brand and Penner 1989).

- Localized removal of sub-surface vegetation: patches or narrow strips of mineral soil are exposed either by removing the surface organic layer or by mixing the surface organic layer with the underlying mineral soil. The composition and structure outside the disturbed area are unchanged; initially there will be no vegetation on the mineral soil, but the vegetation that develops on the mineral soil will be different than the pre-treatment vegetation.

- Extensive removal of sub-surface vegetation: large areas of mineral soil are exposed, which drastically changes the composition and structure of the competing vegetation. Sprouting of the vegetation that originally grew on the site depends on the presence of root systems that have remained in the soil after treatment. When mechanical site preparation removes the duff layer and exposes mineral soil, it creates ideal conditions for seeding by pioneering species, (Walstad and Kuch 1987), and therefore, causes a shift in species composition (Chambers 1991).

One of the objectives of post-harvest mechanical treatments is to redistribute, crush and/or align logging debris or slash. Slash can be an impediment to tree planting and other operations (e.g. tending) that occur on a site after logging. By aligning or redistributing the slash, establishment costs can be reduced. Mechanical crushing of slash before a prescribed fire can also improve fire spread. However, the amount, size and arrangement of slash or downed woody debris (DWD) is important for wildlife habitat and the healthy functioning of ecosystems. Care must be taken to maintain the critical functions of DWD for these values while meeting the regeneration objective.

Some of the operational disadvantages associated with mechanical site preparation are:

- the results are highly variable and largely dependant on operator expertise (Oldford 1983).

- the extent of the treatment may be limited by shallow soils, slopes (limited to slopes of less than 35 per cent), rough terrain (Cantrell 1985), remote or scattered locations (Otchere-Boateng and Herring 1990), or by fresh to wet soils prone to compaction (Malik and Vanden Born 1986).

- it is usually more expensive that the alternatives (Cantrell 1985).

- it can destroy advance regeneration.

- it can promote suckering of unwanted species.

However, mechanical site preparation has a larger treatment window than either herbicides or prescribed burning (Cantrell 1985).

Pre-harvest mechanical site preparation in red and white pine stands is being examined on an experimental basis in Ontario (Bracebridge and Sault Ste. Marie). It appears to have some applicability in stands that have a red pine and white pine component (at least 4 m^2 /ha basal area), that have a low component of hardwoods in the overstory and mid-canopy, and that are targeted for natural regeneration. The advantages of performing the treatment before harvest include:

- securing natural regeneration before harvesting, thus avoiding the cost of growing and planting trees on the site

- establishing regeneration before the site is opened up by the harvesting operation, thus giving the pine a jump-start on the competing vegetation

- preserving the genetic heritage of the parent trees on the site

- more closely mimicking the natural ecological processes associated with white and red pine.

Consult Sutherland and Foreman (1995) for a comprehensive review of the effects of mechanical site preparation. Although it was developed for northwestern Ontario, many of the principles and tables are applicable to conditions within the Great Lakes-St. Lawrence forest.

7.3.1.1 Effects of mechanical site preparation on forest productivity, health and condition

Mechanical site preparation can cause the following: soil compaction, erosion, pudding, and displacement of organic matter and nutrients (Walstad and Kuch 1987; Brand 1991). Increased surface water runoff and sedimentation may occur depending on soil type, operating practices, slope steepness, and distance to water courses (Walstad and Kuch 1987). It can disrupt intermittent streams and seeps and damage natural springs. Mechanical site preparation may reduce the soil moisture available to plants during the growing season (Brand and Penner 1989). When mechanical site preparation removes the organic layer, it reduces soil N and foliar N concentration in white pine seedlings (Brand 1991).

However, most of the negative effects of mechanical site preparation on forest productivity, health and condition can be minimized by reducing the amount of duff and woody material that is displaced and by performing the treatment when site conditions are appropriate. However, when used inappropriately, mechanical site preparation has the potential of creating serious negative effects. It is important to remember that the effects of mechanical site preparation on forest productivity, health and condition are dependant on the site type and the harvesting system used.

To minimize the negative effects of mechanical site preparation on the soil surface, Walstad (1976) recommends the following practices:

- use tracked rather than tire-type vehicles
- use on flat rather than steep terrain (confine machinery to slopes <35 per cent)
- operate on dry rather than wet soils
- leave an undisturbed buffer along streams to filter most of the soil particles that are displaced during site preparation
- follow good soil stewardship, such as working along contours.

Mechanical site preparation can have a negative impact on the nutrient reserves of a site, primarily through the displacement or redistribution of the reserves stored in the logging debris and in the organic and upper soil layers. Studies in British Columbia and Ontario suggest that treatments that have the most impact on soil nutrients and subsequent tree growth are: windrowing (Utzig and Walmsley 1988), blade scarification (MacKinnon and McMinn 1988), and duff removal on infertile sites (Wood and Dominy 1988; Foster and Morrison 1989).

The following techniques can be used to mitigate the effects of mechanical site preparation on the site's nutrient capital:

- Spot scarifying only the microsite in which an individual seedling will be established. This will minimize losses due to leaching (McMinn and Hedin 1990) and will also conserve the nutrient reserves in the undisturbed organic layer and in logging debris (Tappeiner 1971; Alm and Long 1988) close to the growing seedling. The incidence of erosion, another source of nutrient loss, is also reduced (Racey *et al.* 1989).
- Mixing (Foster and Morrison 1989) or inverting the more fertile surface organic layers and the underlying mineral soil (McMinn 1986), instead of completely removing the organic layer. This will preserve the longer-term nutrient status of the site and may enhance tree growth (Sutherland and Foreman 1995). Buried bark and wood can also conserve soil fertility (Binkley 1986).
- Reducing the depth of removal of the organic and mineral soil horizons will help conserve nutrients, which can be particularly important when the sub-soil is infertile.

Extremely shallow soils have a limited store of nutrients and are sensitive to disturbance, as are coarse-textured, excessively well-drained soils, with limited nutrient reserves that reside principally in the surface organic layer and in logging debris. Any treatment of such sites should retain as much of the organic layer and logging debris as possible, or mix the organic and mineral soil layers together. Conversely, in deeper, fine-textured soils with a greater or better-distributed nutrient capital, treatments that remove the surface organic layer and some mineral soil are not as detrimental.

Site preparation may affect wildlife habitat by knocking down standing dead trees, cavity trees, and residual cover. When downed woody debris (DWD) is piled into windrows, the value of the DWD to wildlife is affected. Although some habitat may be produced for some species (e.g. den sites for foxes), it generally reduces the values of the DWD for wildlife (Maser *et al.* 1979). When placed in windrows, DWD:

- does not have the same decomposition and moisture characteristics as logs in contact with the forest floor
- does not provide the important habitat conditions that exist at the contact point between logs and the forest floor
- does not provide the network of travelways as logs dispersed across a cut (Naylor 1994).

Site preparation may create more early successional habitats and conditions needed by some species (e.g., good summer range for deer). Mechanical treatments may reduce the amount of woody browse in the short term, but depending on the timing, it may extend the useful period of browse.

Mechanical site preparation can destroy desirable advance growth and cause root and stem wounds to residual trees thus allowing an entry point for disease organisms. Mechanical site preparation on sites with residual trees (e.g. seeding cut of the shelterwood system) must be shallow to avoid damaging their root systems. The area of highest root biomass is 10 to 30 cm beneath the forest floor. The fine fibrous roots most important for water and mineral absorption are in the top 10 to 20 cm (Farell and Leaf 1974; Fayle 1974; Strong and La Roi 1983).

7.3.1.2 Setting the objectives

A forest manager can use mechanical site preparation to reach a variety of objectives. The objectives may include:

- prepare a seedbed for natural regeneration
- prepare a site for artificial regeneration
- improve spacing of natural/artificial regeneration
- control competing vegetation

- align or redistribute slash
- improve drainage and ameliorate other adverse moisture conditions
- reduce fire hazard
- improve access for future treatments.

A variety of mechanical site preparation equipment and techniques can be used, each tailored to met specific characteristics of soil type, vegetation composition, and terrain (Walstad 1976).

7.3.1.3 Selecting the site

When selecting a site for mechanical site preparation, the following factors should be considered:

- Access: Must be able to move people and equipment to the site at a reasonable cost and during the season the treatment is planned for. Sites that will be logged in the winter may not have good road access in the summer or fall when the mechanical treatment is scheduled.
- Topography: Steep slopes will constrain the area available for safe operation of mechanical equipment.
- Wildlife values: Determine the value of the sites for wildlife and determine whether mechanical site preparation will affect the quality of habitat.
- Overstory - Pre-harvest: Confirm the conifer component, and the component of other species that may seed-in or root-sucker after a disturbance or after harvest. The forest manager should examine both the overstory within the stand and the overstory of the neighbouring stands.
- Understory - Examine the species, size and distribution of understory vegetation. The autecology of the species on the site can help determine the type of equipment that should be used to control the competing vegetation. A forest manager can also confirm the presence or absence of advance regeneration and assess whether a mechanical site preparation treatment is needed.
- Stoniness - Assess the amount of exposed bedrock. This will affect the operability of the machinery.
- Moisture - Examine the site for intermittent streams, standing water in depressions and other moisture related factors that may affect the operability of the site.
- Soils - Confirm the soil texture, coarse fragments, depth of soil, and depth of organic matter. This will help decide on the type of equipment to use.

- Slash - Distribution, size, and decomposition class of logging slash and other debris.

7.3.1.4 Selecting the equipment

Specific criteria that help choose the tool to be used are: objectives, silvicultural system, site conditions, timing during the system, time of year, environmental considerations, cost, and equipment availability. TABLE 7.3.3 lists some of the equipment that is currently used in Ontario. For more information, refer to the various equipment catalogues (e.g. Dominy 1987; Hallman 1993). Forest Engineering Research Institute of Canada (FERIC) reports are also very useful when evaluating different pieces of equipment.

TABLE 7.3.3: Mechanical site preparation equipment used in the renewal of the Great Lakes-St. Lawrence conifer forests of Ontario (Dominy 1987; Bell *et al.* 1992; Hallman 1993; Sutherland and Foreman 1995).

TYPE OF EQUIPMENT	SILVICULTURAL SYSTEM	STATUS	FUNCTION	LIMITATIONS	EFFECTS ON SEEDBED AND COMPETING VEGETATION
Brush cutters Mechanical or manual	Clearcut Shelterwood	Rarely used for site preparation.	Used to mow shrub and tree vegetation of moderate to high density. To improve accessibility of vegetation for chemical treatment.	Productivity is a function of mean diameter and density of vegetation.	Does not affect thickness of organic layer. Can stimulate sprouting and root suckering of hardwood shrub and tree species. Good control of balsam fir.
Piling and clearing rakes, detachable bulldozer teeth Examples: Young's teeth Eden rake Blade rake Raumfix rake Root rake	Clearcut Shelterwood	Common.	Removal or alignment of slash. Displacement of organic matter and/or minor mixing of organic and mineral soil. Can be used to rip up root mat and/or uproot shrubs or small trees. Facilitate access for planters and create plantable microsites in undisturbed or lightly disturbed soil. Soil disturbance for mixed-soil seedbed.	Very large boulders can cause damage to teeth. Requires highly skilled operator to avoid damage to residual trees in shelterwood and to avoid excessive scalping.	Effect on seedbed and competing vegetation depends on depth of tooth penetration into soil and amount of organic layer displacement.
Disk trenchers Examples: TTS disk trencher TTS powered disk trencher Donaren powered disk	Clearcut Shelterwood	Common in clearcuts, rare in shelterwood.	Used to expose mineral soil in trenches. Trenches serve as guides to tree planters where artificial regeneration is used. Can be used for natural regeneration in shelterwoods (small non-powered TTS).	Powered more effective where there is a large build-up of slash. Not effective where there are large boulders. Extreme caution must be taken to avoid damage to residual trees in shelterwood.	Can provide a good seedbed within trenched areas. Competition control can be good within trenches although mineral soil exposure can provide a good seedbed for seed rain by competitors. If root suckering species are present before treatment, their number can increase between trenches.

TABLE 7.3.3: Mechanical site preparation equipment used in the renewal of the Great Lakes-St. Lawrence conifer forests of Ontario (Dominy 1987; Bell *et al.* 1992; Hallman 1993; Sutherland and Foreman 1995).

TYPE OF EQUIPMENT	SILVICULTURAL SYSTEM	STATUS	FUNCTION	LIMITATIONS	EFFECTS ON SEEDBED AND COMPETING VEGETATION
trencher					
Patch scarifiers Examples: Leno scarifier Bräcke scarifiers Donaren scarifier	Clearcut Shelterwood	Common in clearcuts, some use in shelterwood.	Used to expose mineral soil in patches at intervals. Patches serve to guide tree planters where artificial regeneration in used. Useful where erosion may be a concern. Can have simultaneous scarification and seeding (Bräcke). Leno scarifiers are smaller and can be used in shelterwood conditions.	Not effective where there is a large build-up of slash.	Can provide a good seedbed on patches. Competition control can be good in patches although mineral soil exposure can provide a good seedbed for seed rain by competitors. If root suckering species are present before treatment, their number can increase between patches.
Straight blades Examples: Small tracked bulldozers with 6-way blades. Large bulldozers Skidder blades	Shelterwood (small bulldozers) Clearcut (large bulldozers and skidder blades)	Common	Re-aligns slash, knocks over undesirable residual trees. Displaces various amounts of organic layer. Trampling of heavy residuals prior to prescribed burning. Creates planting microsites. Commonly used to create corridors on backlog sites or areas with heavy residuals and slash.	Requires highly skilled operator to avoid damage to residual trees in shelterwood and to avoid excessive scalping. Increasing size of machine is required with increasing slash loads.	Seedbed suitability and competition control depends on the depth of blading.
Mixers Examples: Meri-crusher Rototillers	Clearcut Shelterwood	Experimental in Ontario.	Used to mix mineral soil and organic layers to create a seedbed for natural regeneration, planting spots for artificial regeneration. Mulches slash and vegetation on the site.	Lower productivity on sites with excessive slash. Not suitable for sites with large boulders or extreme stoniness. Care must be taken to avoid damage to residual trees.	Creates good seedbed for natural regeneration; may stimulate dormant seeds in seed bank and root suckering species. Controls sprouting of shrubs and undesirable hardwood stems. May create

TABLE 7.3.3: Mechanical site preparation equipment used in the renewal of the Great Lakes-St. Lawrence conifer forests of Ontario (Dominy 1987; Bell *et al.* 1992; Hallman 1993; Sutherland and Foreman 1995).

TYPE OF EQUIPMENT	SILVICULTURAL SYSTEM	STATUS	FUNCTION	LIMITATIONS	EFFECTS ON SEEDBED AND COMPETING VEGETATION
					suitable seedbed for seed rain by competitors on moist sites.
Drag scarifiers Examples: Spiked anchor chains or barrels and chains	Shelterwood Clearcut	In shelterwood, experimental in Ontario, common in clearcuts	Screefed, trenched, and some mixed microsites for planting, direct and natural seeding. Reduce or align slash and to expose moist duff or mineral soil to prepare sites for natural or artificial regeneration. Can be used before or after a herbicide application to control hardwood shrubs and trees. Versatile: different designs and weights can used to achieve different objectives.	Not effective where there is a large slash build-up. Care must be taken to avoid damaging residual trees.	Creates a good seedbed. Has a stimulating effect on seedbanking and root suckering species. Can also stimulate sprouting. On moist sites, may provide good seedbed for seed rain by competing species. On rich sites, should be combined with a chemical treatment for competition control.
Excavator with rake attachment	Clearcut Shelterwood	Experimental in Ontario	Used to align slash, remove upper layer of thick organic mat, creates some mixing of organic and mineral soil. On shelterwood sites, it can be used before or after regeneration cut to create good seedbed for natural regeneration with very low potential to damage residual trees.	Not yet known	Effect on seedbed and competing vegetation depends on depth of tooth penetration into soil and amount of organic layer displacement.

7.3.1.5 Assessing the effects of treatment

Refer to: *Standard assessment procedures for evaluating silvicultural equipment: a handbook* (Sutherland 1986) for a methodology for assessing the effects of mechanical site preparation. It includes procedures to record:

- site conditions that are likely to affect and/or be changed by the equipment before treatment
- events during the treatment operation
- results obtained from the treatment in relation to the objectives.

7.3.1.6 Ecosite specific considerations

Based on the general characteristics of ecosites, a knowledge of the autecology of both crop and non-crop vegetation (***see*** Section 3.4.7 “Autecology of Associated Species”), and the effect of different equipment on soils and site features, management interpretations can be developed to help prescribe mechanical site preparation treatments. However, each site should be examined to determine the local conditions, which may not be the same as the average ecosite condition.

In this section, the susceptibility of the ecosites to site damage from mechanical site preparation treatments and the use of mechanical site preparation for seedbed preparation, vegetation control, and other objectives by ecosite will be discussed.

Some ecosites are more prone to site damage than others. Some of the characteristics that are important when examining the effect of mechanical site preparation on ecosites are discussed in Section 9.0 “Harvesting Considerations”.

Interpretations for northwestern or northeastern Ontario ecosites or site types can be made by examining the ecosite equivalency table (TABLE 3.0.3) in Section 3.0 “Characteristics of the Great Lakes-St. Lawrence Conifer Forest” and using information presented in this guide on the autecology of both crop and non-crop vegetation (***see*** Section 3.4.7 “Autecology of Associated Species”) and the effect of different equipment on soils and site features (described earlier in this section).

Central Ontario ES 11.1, 11.2, 12.1, 12.2, 13.1, 13.2

These sites are usually managed for pine under the shelterwood system. Pre-harvest or post-harvest mechanical site preparation can be used. When site preparation occurs at the same time as a good seed year, these ecosites should successfully regenerate naturally without the need for planting.

CONSIDERATIONS

- Many of these ecosites have shallow soils and shallow organic mats. The feeder roots of overstory trees are close to the surface and care should be taken during logging and mechanical site preparation to avoid compaction, rutting, and removing the duff layer. Be especially cautious on ES 13.1 where 55 per cent of the sites have <30 cm of soil and 90 per cent have <10 cm of organic matter.

- Be aware of slopes on these ecosites. Over 65 per cent of the sites are on slopes, with over 35 per cent being on the upper slope position.

- 45 to 70 per cent of these ecosites have coarse soils. The bulk of the nutrients are stored in the organic layer. Removal or displacement of the organic layer from areas where regeneration is expected to establish is not recommended. In addition, when the organic layer is removed on the sites, they become very prone to erosion.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural white and red pine regeneration. However, if the site is prone to drying out (more common on type "x.1" sites), mineral soil exposure may be required to provide a moist enough seedbed. Because shallow organic layers and shallow soils are common on these ecosites, and many of the sites occur on slopes, scarifiers that result in patches (e.g. excavators with rake attachment) as opposed to broadcast treatments may be more appropriate.

VEGETATION MANAGEMENT

These ecosites have 10 to 15 percentage coverage of balsam fir, 10 to 15 percentage coverage of red maple and 10 to 20 percentage coverage of hardwood shrubs (beaked hazel is most common species) in the understory. Vegetation management can be done selectively. The red maple and hazel stems can be uprooted. Red maple roots in the mineral soil and hazel in the organic, so ensure that the treatment is deep enough to prevent sprouting. Balsam fir can be knocked over or cut and pushed into several small piles (as opposed to windrowed or pushed into a few large piles). Areas with advanced conifer crop tree regeneration can be identified and protected.

One mechanical site preparation treatment should be enough to control the competing vegetation on these ecosites, especially ES 11.1, 11.2. White birch in the overstory may seed-in on scarified patches where mineral soil is exposed on ES 12.1, 12.2. Trembling aspen may produce root suckers following logging and site preparation on ES 13.1, 13.2. Type "x.2" ecosites are likely to have quicker recovery of understory vegetation following the mechanical site preparation treatment. Therefore, the timing of the site preparation treatment with a good seed year is especially critical on those ecosites. A follow-up chemical site preparation or a tending treatment may be required.

Central Ontario ES 14.1, 14.2

These ecosites are good candidates for a mechanical site preparation treatment and can be managed for both red oak and white pine under the shelterwood system. When mechanical site preparation occurs at the same time as a good seed year, natural white pine regeneration will be promoted.

CONSIDERATIONS

- Shallow organic mat (over 85 per cent of sites have less than 10 cm of organic matter). Mechanical site preparation treatments do not have to be very deep.

- Be aware of slopes on these ecosites. Over 80 per cent of the sites are on slopes, with over 50 per cent being on the upper slope position.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural white pine regeneration.

VEGETATION MANAGEMENT

These ecosites have 5 to 10 percentage coverage of balsam fir, up to 30 percentage coverage of red maple, red oak and hard maple, and between 15 to 20 percentage coverage of hardwood shrubs (beaked hazel most common species) in the understory. The red maple, hard maple and hazel stems can be uprooted. Red maple and hard maple roots are in the mineral soil, and hazel roots are in the organic, so ensure that the treatment is deep enough to prevent sprouting. Areas with advanced red oak and white pine regeneration can be identified and protected.

White birch and red maple in the overstory may seed-in on scarified patches where mineral soil is exposed. Trembling and largetooth aspen may produce root suckers following logging and site preparation. Seedbanking species and seed rain will colonise the mineral soil exposed by the treatment. Type "x.2" ecosites are likely to have quicker recovery of understory vegetation following the mechanical site preparation treatments and therefore, the timing of the treatment with a good seed year is especially critical on those ecosites. A herbicide site preparation treatment and/or a tending treatment may be required on these ecosites, especially on ES 14.2. Herbicide treatments should avoid areas with red oak regeneration.

Central Ontario ES 16.1

This ecosite, when managed to promote a component of natural white pine seedlings, is a good candidate for pre-harvest mechanical site preparation. Depending on the white pine component, the sites can be managed using the shelterwood system, or the clearcut system with seed trees. Scarification in conjunction with a good seed year can help secure natural regeneration.

CONSIDERATIONS

- Shallow organic mat: 50 per cent of sites have less than 10 cm of organic matter. Mechanical site preparation treatments do not have to be very deep.

- Shallow soils: 60 per cent of sites have <30 cm of mineral soil and exposed bedrock covers 10 per cent of sites. Mechanical site preparation treatments should not be very deep and should be targeted to areas of deeper soils.

- Be aware of slopes: 70 per cent of sites are on slopes, with over 50 per cent being on the upper slopes.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 “Determining Seeding Rates”). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed under moist conditions for natural white pine regeneration. Mineral soil exposure may be required on dry sites and to promote red pine regeneration. Scarification can be done pre-harvest and the seedbed should remain suitable for 2 to 3 years because of a lack of hardwood in the overstory and understory.

VEGETATION MANAGEMENT

These ecosites have high levels of conifer regeneration and very low levels of hardwood regeneration and shrubs. Balsam fir makes up 10 percentage coverage of the conifer regeneration, with the remaining 25 percentage coverage of consisting of black spruce, white pine and cedar. Balsam fir can be controlled by cutting or knocking it over and pushing it into small piles (as opposed to windrowed or pushed into a few large piles). Areas with advanced crop tree regeneration can be identified and protected.

Central Ontario ES 17.1, 17.2, 18.1, 18.2, 19.1, 19.2

These ecosites are good candidates for a mechanical site preparation treatment. These sites are managed using a variety of different silvicultural systems depending on the overstory composition. When managed under the shelterwood system and mechanical site preparation occurs at the same time as a good seed year, these ecosites should successfully regenerate naturally to conifer crop tree species although a chemical site preparation or tending treatment may be required. Supplemental planting may also be required to ensure sufficient stocking when the treatment is not applied in a good seed year or if an insufficient number of seed trees are left on the site.

CONSIDERATIONS

- Shallow organic mat (over 70 per cent of sites have <10 cm of organic matter). Mechanical site preparation treatments do not have to be very deep.
- 60 per cent of the drier ("x.1") ecosites have coarse soils. The bulk of the nutrients are stored in the organic layer. Removal or displacement of the organic layer from areas where regeneration is expected to establish is not recommended.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural conifer regeneration. On drier sites, patches of mineral soil exposure may be required to create a moist enough seedbed.

VEGETATION MANAGEMENT

These ecosites have 10 to 20 percentage coverage of balsam fir and 30 to 40 percentage coverage of beaked hazel and mountain maple in the understory. Balsam fir control can be achieved by knocking it over or cutting it and pushing it into small piles (as opposed to windrowed or pushed into a few large piles). The hazel and mountain maple stems can be uprooted. Areas with advanced crop tree regeneration can be identified and protected.

White birch in the overstory may seed-in on scarified patches with mineral soil exposure. Seedbanking species and seed rain will colonise the mineral soil exposed by the treatment. Trembling aspen will produce numerous root suckers following harvesting and mechanical site preparation. A herbicide site preparation or a tending treatment will likely be required on these ecosites.

Central Ontario ES 20.1, 20.2

These sites are usually managed for white and red pine and white spruce under the shelterwood system. When mechanical site preparation occurs at the same time as a good seed year, these ecosites should successfully regenerate naturally to conifer crop tree species although a chemical site preparation or tending treatment may be required. Supplemental planting may also be required to ensure sufficient stocking when the treatment is not applied in a good seed year.

CONSIDERATIONS

- Shallow organic mat (over 70 per cent of sites have <10 cm of organic matter). Mechanical site preparation treatments do not have to be very deep.

- Be aware of slopes on these ecosites. Over 70 per cent of these ecosites are on slopes, with over 30 per cent being on the upper slope position.

- 40 to 60 per cent of ES 20.1 and ES 20.2 have coarse soils. The bulk of the nutrients are stored in the organic layer. Removal or displacement of the organic layer from areas where regeneration is expected to establish is not recommended. In addition, when the organic layer is removed on the sites, they become very prone to erosion.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural conifer regeneration. On drier sites, patches of mineral soil exposure may be required to create a moist enough seedbed.

VEGETATION MANAGEMENT

These ecosites have 20 to 25 per cent balsam fir, up to 15 per cent red maple and 25 to 30 per cent hardwood shrubs (beaked hazel and mountain maple are the most common species) in the understory. Balsam fir control can be achieved by knocking it over or cutting it and pushing it into small piles (as opposed to windrowed or pushed into a few large piles). The red maple, hazel and mountain maple stems can be uprooted. Red maple roots in the mineral soil, and hazel and mountain maple in the organic, so ensure that the treatment is deep enough to prevent sprouting. Areas with advanced white pine and white spruce regeneration can be identified and protected.

White birch in the overstory may seed-in on scarified patches where mineral soil is exposed. Trembling aspen may produce root suckers following logging and site preparation. Seedbanking species and seed-rain will colonise the mineral soil exposed by the treatment. Type "x.2" ecosites are likely to have quicker recovery of understory vegetation following the mechanical site preparation treatments and therefore, the timing of the treatment with a good seed year is especially critical on those ecosites. A follow-up chemical site preparation treatment and/or a tending treatment may be required on these ecosites.

Central Ontario ES 21.1, 21.2

These ecosites are good candidates for a mechanical site preparation treatment. These sites are managed for white pine or cedar using a variety of different silvicultural systems depending on the overstory composition. When mechanical site preparation occurs at the same time as a good seed year, these ecosites should successfully regenerate naturally to conifer crop tree species although a chemical site preparation or tending treatment may be required. Supplemental planting may also be required to ensure sufficient stocking when the treatment is not applied in a good seed year.

CONSIDERATIONS

- Shallow organic mat (over 50 per cent of sites have <10 cm of organic matter). Mechanical site preparation treatments do not have to be very deep.

- 30 per cent of these ecosites have coarse soils. The bulk of the nutrients are stored in the organic layer. Removal or displacement of the organic layer from areas where regeneration is expected to establish is not recommended.

- 20 per cent of ES 21.2 have organic soils and are not operable during the summer months. Site preparation treatments are usually targeted at the upland portion of these ecosites.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural conifer regeneration. On drier sites, patches of mineral soil exposure may be required to create a moist enough seedbed. Cedar prefers a constantly moist seedbed, and seems to prefer moist decaying logs. If the objective is to promote cedar regeneration, the operator should avoid disturbing existing moss-covered down woody debris.

VEGETATION MANAGEMENT

These ecosites have 15 to 20 percentage coverage of balsam fir, up to 10 percentage coverage of red maple and white birch, and 10 to 20 percentage coverage of hardwood shrubs (beaked hazel and mountain maple most common species) in the understory. Balsam fir control can be achieved by knocking it over or cutting it and pushing it into small piles (as opposed to windrowed or pushed into a few large piles). The red maple, hazel and mountain maple stems can be uprooted. Areas with advanced white spruce and cedar regeneration can be identified and protected.

White birch in the overstory may seed-in on scarified patches where mineral soil is exposed. Seedbanking species and seed rain will colonise the mineral soil exposed by the treatment. A herbicide site preparation treatment and/or a tending treatment may be required on these ecosites.

Central Ontario ES 30.1, ES 30.2

These ecosites are good candidates for a light mechanical site preparation treatment. These sites are usually managed for hemlock, but they can be targeted for white pine or red spruce restoration. When mechanical site preparation occurs at the same time as a good seed year, these ecosites should successfully regenerate naturally, although a chemical site preparation or tending treatment may be required. Supplemental planting may also be required to ensure sufficient stocking when the treatment is not applied in a good seed year.

CONSIDERATIONS

- Be aware of slopes on these ecosites. Over 70 per cent of the sites are on slopes, with over 25 per cent being on the upper slope position.

SEEDBED PREPARATION

Mechanical scarification may be required to meet seedbed preparation targets (***see*** Section 7.4.3 "Determining Seeding Rates"). Scarification can be done pre-harvest or post-harvest. A light scarification treatment to remove the litter layer of the forest floor should be sufficient to create a good seedbed for natural hemlock regeneration. However, if the site is prone to drying out (more common on "x.1" sites), mineral soil exposure may be required to provide a moist enough seedbed. The success of this treatment will depend on good control of understory hardwood competition.

VEGETATION MANAGEMENT

These ecosites have 10 percentage coverage of balsam fir, <10 percentage coverage of red maple, and <15 percentage coverage of hardwood shrubs (striped maple, mountain maple, and beaked hazel most common species) in the understory. Vegetation management can be done selectively. The hardwood shrubs can be selectively uprooted. Balsam fir can be knocked over and pushed into several small piles (as opposed to windrowed or pushed into a few large piles). Areas with advanced conifer crop tree regeneration can be identified and protected.

The mechanical site preparation treatment should be enough to control the competing vegetation on these ecosites, however a tending treatment may be required to control sprouting hardwoods and seedbanking species (e.g. raspberry).

Central Ontario ES 32

These ecosites are dominated by wet organic soils, with some fresh to very moist mineral soils. Site preparation can be done in the winter and will be targeted at knocking over balsam fir and compacting the mosses to provide a good seedbed for cedar and red spruce. Operational experience on these ecosites is limited.

Central Ontario ES 22, 33

Seventy per cent of ES 22 have shallow organic mats and site disturbance should be assessed following harvesting to see if seedbed targets have been met. Site preparation for vegetation management purposes is aimed at knocking down the balsam fir, compacting the slash to speed up it's decomposition and to reduce hare habitat, and to compress the mosses to improve the seedbed for cedar. Hardwood shrubs (mountain maple and beaked hazel) and red maple can be uprooted using rakes or blades. Mechanical site preparation can be done pre-harvest to establish advance regeneration, however it should not be designed provide a continuous flat surface. Site preparation treatments should attempt to mimic the typical pit and mound micro-topography that occurs naturally on these sites. Chemical site preparation or a tending treatment may be required to control sprouting and aspen root suckers, as well as seedbanking species.

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7.3.2 Chemical Site Preparation

by Andrée E. Morneault and Robert A. Campbell

Chemical site preparation is the use of a herbicide to control non-crop vegetation before establishing natural or artificial regeneration. It does not attempt to eliminate plant species, but to control those that are potential competitors for 2 to 3 years after germination or planting to allow crop trees to grow freely and become established.

The purpose of chemical site preparation is to control existing competing vegetation and/or to prevent new competitors from becoming established on a site. It often results in better crop tree response than tending treatments because crop trees do not suffer competition during their first growing season after out-planting or germination (Sutton and Weldon 1993; Wood and von Althen 1993). White and red pine can suffer growth loss even when competition control is delayed until 1 year after establishment (Wagner *et al.* 1996). Higher herbicide rates can be used with chemical site preparation compared to chemical tending, allowing better control of some species of competing vegetation. The application window is wider than with chemical tending because there is no need to wait for crop trees to harden off. In addition to offering more flexibility in timing, this also provides an opportunity to apply the herbicide earlier in the season (early to mid-July) when some plants are more susceptible (e.g. raspberry, bracken fern).

Chemical site preparation gives better control of existing competing vegetation than mechanical site preparation or prescribed fire because it kills plants that reproduce vegetatively. It does not disturb the soil, therefore seeds in the seedbank and wind-borne seeds are not given increased opportunity over that created by the logging disturbance. Provided that advance regeneration is hardened off, it is not damaged by the herbicide application. However, chemical site preparation does not provide site disturbance, and therefore does not create a good seedbed for many conifer species, and it does not change the distribution of slash on the site.

Chemical treatments can be used to facilitate prescribed burns by killing and drying vegetation before the fire. They can also be used before or after a prescribed burn or mechanical site preparation treatment to provide vegetation control while other methods provide seedbed preparation and slash management.

7.3.2.1 Herbicides available for chemical site preparation

Five herbicides, (glyphosate, 2,4-D, hexazinone, triclopyr and simazine) are commonly used for forest management in Ontario. In 1995, glyphosate was applied to 89.1 per cent of the total area of Crown land treated with herbicide; 2,4-D , 8.2 per cent; triclopyr, 1.9 per cent; and hexazinone, 0.8 per cent (Canadian Council of Forest Ministers, National Forestry Database, 1996). Simazine was not applied to Crown land in 1995 but was used on private land, especially for plantation establishment on former agricultural lands. For general information on the use of these herbicides refer to McLaughlan *et al.* (1996b) and Williamson and Lane (1989). For information on chemistry, uptake, translocation, mode of action, and formulations, please consult the *Herbicide Handbook* (Ahrens 1994) and technical notes published by the Canadian Pulp and Paper Association. Information from these sources has been summarized in TABLES 7.3.4, 7.3.5 and 7.3.6. For up-to-date information on application rates and use, please consult product labels. For information on the susceptibility of individual species to the different herbicides, please consult the appropriate autecology guides or information notes (Sims *et al*. 1990; Bell 1991; Buse 1992a, 1992b; Buse and Bell 1992; Hollstedt 1992; Louter *et al.* 1993; Bentley and Pinto 1994; Arnup *et al.* 1995; Mallik *et al.* 1996). Selected information from these publications is summarized in TABLE 7.3.7.

7.3.2.2 Methods for herbicide application

Herbicides can be applied in several ways: aerially, using a backpack sprayer, using a vehicle- mounted ground sprayer, stem injection, cut and swab, spot gun, or basal spray. In the Great Lakes-St. Lawrence forest, the most common methods of applying herbicides are vehicle- mounted ground sprayers (most commonly, the airblast sprayer Desrochers and Dunnigan [1991]) following a shelterwood cut, and aerial application of herbicides for plantations established following a seed tree cut or clearcut with standards.

For detailed information on the equipment and methods used to apply herbicides, please refer to Hardy (1987), Otchere-Boateng and Ackerman (1990), Desrochers and Dunnigan (1991) and McLaughlan (1992).

AERIAL APPLICATION

When aerial application methods are used, herbicides are sprayed in liquid solution either from a helicopter or a small fixed wing aircraft. This method is generally used on large operating units because they can be treated in a relatively short time. This method is also very useful on sites that have poor access or that have site features that limit the operability of ground equipment. Uniform application of herbicides is more likely than with ground spraying equipment because aerial equipment can travel at a relatively uniform speed and follow straight lines. However, there is a greater probability of off-target deposit. When spraying areas adjacent to water bodies, off-target deposition can be mitigated through the use of buffer strips. Aerial application is used to control a wide variety of broadleaved vegetation and grasses. While generally recognized as a very effective method of controlling competing vegetation, it is high profile and controversial. *Vision*® (glyphosate) is by far the most commonly used chemical, although 2,4-D has been used in small amounts, and *Release*® (triclopyr) and *Velpar-L*® (hexazinone) are registered for aerial application. For a general overview on aerial application equipment and drift prediction tools, refer to McLaughlan *et al.* (1996a). There is a very detailed planning and implementation process for aerial spraying in Ontario that is described in the Ministry of Natural Resources "*Aerial Spraying for Forest Management*" manual (OMNR 1991).

TABLE 7.3.4: Active ingredient, trade names, Pesticide Control Product number (PCP), and permitted use for the five most common herbicides available for use in forestry (*adapted from*: McLaughlan *et al.* 1996)

ACTIVE INGREDIENT	PCP	TRADE NAME	PERMITTED USE					
			Release	Site Preparation	Individual Woody Plant Treatment			
					INJECT	SOIL	BASAL	STUMP
Glyphosate	19899	Monsanto *Vision*® Forestry Herbicide	A/G	A/G			×	×
	21262	Monsanto *Ezject*® Herbicide Capsules					×	×
Hexazinone	18197	Dupont *Velpar L*® Herbicide	G	A/G		×		
	21389	Dupont Pronone 5G		A/G		×		
	21390	Dupont Pronone 10G		A/G		×		
Simazine	16370	Ciba-Geigy Princep Nine-T	G	G				
	16049	Pfizer Simazine 80W	G					
	17697	Clean Crop 80% WP Simazine Herbicide	G					
Triclopyr	22093	Dow Elanco *Release*® Silvicultural Herbicide	A/G	A/G			×	×
2,4-D amine	16994	Dow Formula 40F Forestry Herbicide			×			×
	16995	Clean Crop Forestamine Liquid Herbicide for			×			×
	18067	Forestry			×			×
	18075	Clean Crop Sure-shot 5000 Liquid Herbicide			×			×
	18113	Clean Crop Sure-Shot Forestamine			×			×
	11441	Sanex Amine 500 Forestry Herbicide						
		Van Waters and Rogers Guardsman			×			×
		2,4-D Amine 500 Liquid Weedkiller						
2,4-D ester	15981	Dow Esteron 600 Forestry Herbicide	A/G	A/G	×		×	×
	14739	Rhone Poulene Estasol 2,4-D Ester LV 600						
		Emulsifiable Liquid Herbicide	A	A				
	9561	Clean Crop 2,4-D Ester 600 Herbicide	A/G	A/G	×		×	×
	16675	Clean Crop For-ester E.C. Forestry Herbicide	A	A	×			

								×	×

A = Aerial application; G = Ground application

TABLE 7.3.5: Five most common herbicides available for use in forestry (*adapted from*: Otchere-Boateng [1990]; Arnup *et al.* [1995]; McLaughlan *et al.* [1996b]).

HERBICIDE	SOIL TYPES	TARGET VEGETATION	MODE OF ACTION	APPLICATION CRITERIA	COMMENTS
Glyphosate	No restrictions	Broad spectrum control (annual and perennial grasses, annual and perennial herbs, poplar, birch, maple, cherry, hazel, blueberry, sweetfern, *rubus* spp., bracken fern, willow, alder, etc.). Poor control of thick cuticle leaved species such as sugar maple. Control of red maple increases with late season application. Best results for bracken fern will be obtained from applications made after frond tips have uncurled but before senescence (Williamson and Lane 1989).	Inhibits the formation of an essential amino acid in plants, causing metabolic failure and death. *Vision*®: Absorbed through leaves, translocates though plant. *Ezject*®: If material in xylem, will move up to foliage, if material in phloem, will move to roots.	*Vision*®: Aerial or ground application to actively growing vegetation. For site preparation (late June to late July) or release (after buds harden off in conifers, mid-Aug. to mid-Sept.). Better control later in growing season, when higher rates of translocation from crown to roots occurs. *Ezject*®: Inject the appropriate number of capsules evenly at base of tree or stump below all major branches. Can be treated any time of year, except when wood is frozen.	Apply before killing frost. Some autumn colours are acceptable, provided no major leaf fall has taken place in undesirable brush and tree species. Lowest rates can be used when incomplete control of competing vegetation is required. Lower rates are recommended when white pine is newly planted or when natural regeneration is 1-3 years old. Do not spray during drought, within 6 hours of rain, or when target vegetation is stressed or damaged. Need clean water to mix. Low spray volumes are more effective than high spray volumes. Completely biodegradable, does not leach and cannot accumulate in food chain (Monsanto Canada, Inc. 1992). More effective on moist vegetation, when RH is high and air is warm (>15°C) (Williamson and Lane 1989). Is most effective on broadleaved plants when they are close to flowering but before senescence (Williamson and Lane 1989). There is no evidence of translocation across root grafts to untreated trees (flashback) after a stem injection treatment (Williamson and Lane 1989).

Continued...

TABLE 7.3.5: Five most common herbicides available for use in forestry (*adapted from*: Otchere-Boateng [1990]; Arnup *et al.* [1995]; McLaughlan *et al.* [1996b]).

HERBICIDE	SOIL TYPES	TARGET VEGETATION	MODE OF ACTION	APPLICATION CRITERIA	COMMENTS
2,4-D Ester: foliar Amine salt: cut surface	No restrictions	Ester: alders, balsam, birch, cherries, raspberries, elderberry, elm, hazel, poplars, sumac, willow and herbaceous broad-leaved species. Does not control sedges or grasses. Not effective on maple or oak species. Re-sprouting can be a problem (Sajdak 1985). Amine salt: alder, willow.	Ester absorbed through leaves and translocated within phloem, accumulates in meristematic regions of shoots and roots. Interferes with normal cell growth, impairs respiration, food reserves, and cell division. Amine salt absorbed through roots and moves through phloem.	Ester: Aerial or ground application for site preparation and conifer release. For conifer release, delay spray until crop tree buds have hardened-off and use lower rates. For site preparation, higher rates can be used and the application should be after full leaf expansion and during the period of active growth. Amine: Apply to frills or hacks cut into bark or tree. Can be applied to freshly cut stumps with brush or backpack sprayer.	Application must be made before frost. Can damage crop trees at high rates; lower rates should be used in pine plantations. Do not spray during rain or drought. Most effective between April and end of July. The ester formulation can vaporize and move off site when temperatures are greater than 32°C (Boyd *et al.* 1985).

Continued...

TABLE 7.3.5: Five most common herbicides available for use in forestry (*adapted from*: Otchere-Boateng [1990]; Arnup *et al.* [1995]; McLaughlan *et al.* [1996b]).

HERBICIDE	SOIL TYPES	TARGET VEGETATION	MODE OF ACTION	APPLICATION CRITERIA	COMMENTS
Hexazinone	Do not use on gravelly or rocky soils, sandy or coarse textured soils or exposed sub-soils. Do not apply on coarse textured soils with less than 2% organic matter or on fine soils with less than 1% organic matter. The heavier the soil, the higher the rate of *Velpar L*® needed. Do not apply on frozen and snow covered soils and water saturated sites. Do not use on sloped sites with high run-off potential or on erosion-prone sites.	Annual, biennial, and perennial weeds, grasses and woody plants e.g. grasses, raspberry, and aster are very susceptible; maple, willow, poplar, and birch are intermediate in tolerance; hazel, alder, blueberry and dogwood are tolerant. The residual activity reduces germination of species with wind-borne seed and seedbanking species and can reduce sprouting of certain other species (McLaughlan *et al*., 1996b).	Absorbed through the roots, translocated upward through the xylem. Photosynthetic inhibitor. Residual and contact control. Tolerant plant species are able to metabolize the herbicide into non-toxic metabolites (Campbell *et al*., 1996).	*Velpar L*®: Broadcast ground application and undiluted spot treatments for site preparation and conifer release. Aerial (since 1991) for site preparation. Pronone: Ground application for site preparation. For grass and herbs, apply broadcast in the spring before the leaves are fully expanded. For shrub and tree control, for conifer release, apply directly to the soil as close as possible to base of target vegetation.	Herbaceous vegetation will show effect within 2-6 weeks, depending on humidity and temperature. For brush and trees, effect appears within 3 weeks after sufficient rainfall carried product to root zone. If dose if 9.0 l/ha or less, black spruce, white spruce or red pine can be planted. If rate is higher, wait one year before planting. Do not apply within 50 m of water. Moisture activates herbicide. Soil must be moist at time of application and 6-13 mm of rainfall is needed within 2 weeks after application. Application rates must be very precise. Do not apply within 1 m of crop trees. White pine and jack pine can be susceptible.

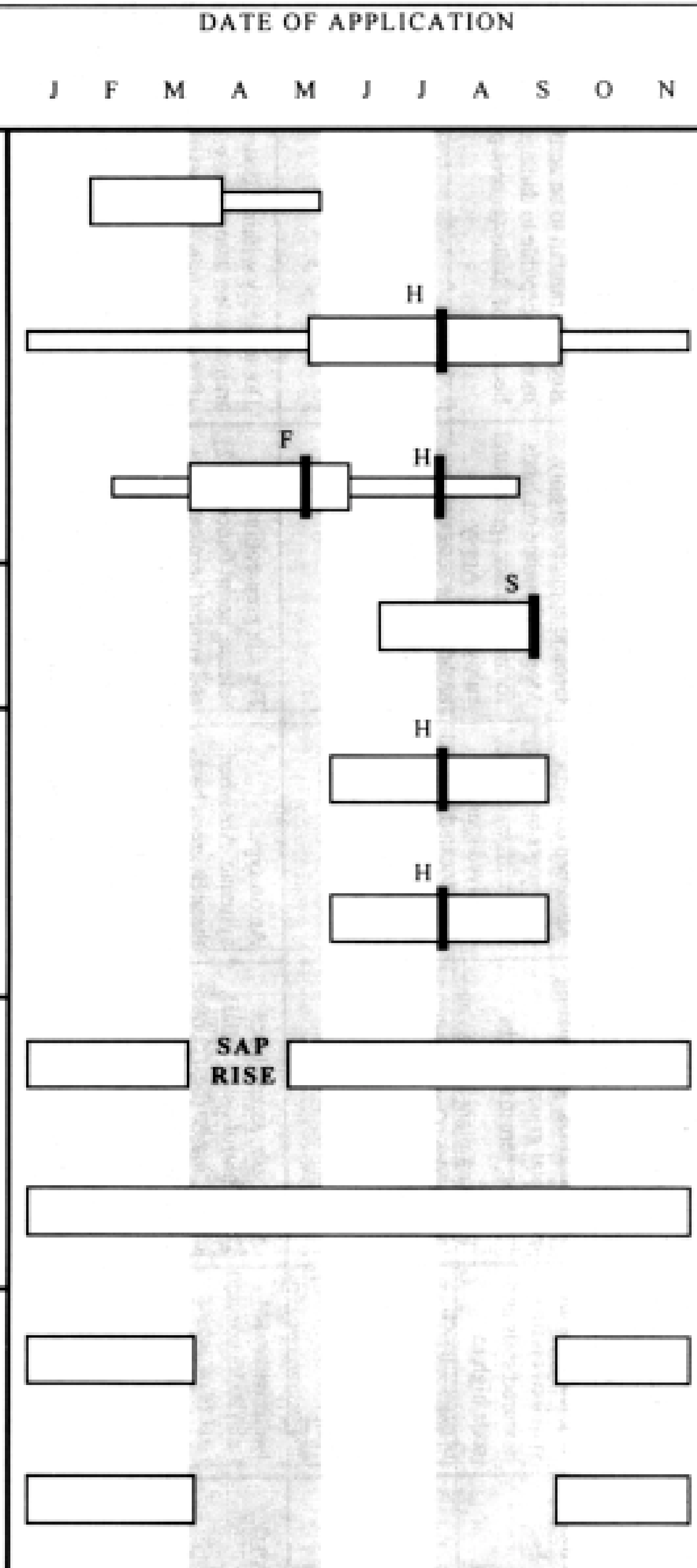
Continued...

TABLE 7.3.5: Five most common herbicides available for use in forestry (*adapted from*: Otchere-Boateng [1990]; Arnup *et al.* [1995]; McLaughlan *et al.* [1996b]).

HERBICIDE	SOIL TYPES	TARGET VEGETATION	MODE OF ACTION	APPLICATION CRITERIA	COMMENTS
Simazine	Highest rates are required on fine-textured soils and soils high in organic matter. Do not apply on frozen and snow covered soils and water saturated sites.	Annual grass, germinating perennial grass, and triazine-sensitive herbs. Resistant plant species may invade site (Ont. Weed Comm. 1995).	Absorbed through plant roots by mass flow with water and dissolved ions. Translocated upward in plant through xylem. Inhibits photosynthesis.	Ground application only. Most appropriate on lands formerly under agricultural cultivation. Apply broadcast or selectively in spring or fall before freeze-up.	Requires rainfall to be activated. Container stock is more susceptible to damage than bareroot stock because of shallower root position.
Triclopyr	No restrictions.	Alder, ash, aspen, birch (best control using foliar), cherry, maple (best control using basal bark), raspberry. Does not control grasses.	Auxin-type, systemic. Absorbed through green bark, leaves and roots and translocated throughout plant, causes plant's growth system to malfunction.	For site preparation or release, aerial (since 1992) and ground application as foliar spray, early June-July for site preparation, mid-Aug. to killing frost for release; basal bark, and stem treatment during active growing season or dormant season.	Do not spray within 2 hours of rain. No evidence of translocation across root grafts to untreated trees after a stem injection treatment (Williamson and Lane 1989). Extreme care must be taken around water bodies and water courses including intermittent streams that may provide brook trout habitat. Pines are more susceptible than spruces. Ensure that crop trees have hardened-off completely.

TABLE 7.3.6: Timing of herbicide application for selected herbicides to achieve optimum control of selected competing vegetation (*adapted from*: Williamson and Lane 1989)

WEED TYPE	HERBICIDE
Grass and Grass-Herbaceous Weed Mixtures *Foliar spray or granular application*	Atrazine
	Glyphosate
	Hexazinone
Bracken *Foliar spray*	Glyphosate
Woody Weeds *Foliar spray*	Glyphosate
	Triclopyr
Woody Weeds *Stem treatments*	Glyphosate
	Triclopyr
Woody Weeds *Cut stump treatments*	Glyphosate
	Triclopyr



F = flushing period H = earliest date of hardening-off of crop S = commencement of senescence of weeds

For illustrative guidance only; individual seasons may show divergence from these limits. [ ] = optimum period for weed control.

TABLE 7.3.7: Susceptibility of selected species to the 5 most common herbicides registered for forestry use in Ontario (*adapted from*: Bovey 1977; Arnup *et al.* 1995; McLaughlan *et al.* 1996b).					
SPECIES	GLYPHOSATE	2,4-D	HEXAZINONE	TRICLOPYR	SIMAZINE
Abies balsamea Balsam fir	R	R	R	R	R
Acer rubrum Red maple	S	I-R	S-I	S-I	—
Acer saccharum Sugar maple	S-I	I-R	—	S-I	—
Acer spicatum Mountain maple	S-I	I-R	I	S	—
Alnus incana ssp. *rugosa* Speckled alder	S-I	S-I	R	S	—
Alnus viridis ssp. *crispa* Green alder	S	S-I	R	S	—
Amelanchier spp. Serviceberries	S	S	I	S	—
Aster macrophyllus Large-leaved aster	—	—	S	—	—
Betula alleghaniensis Yellow birch	S	S	—	S	—
Betula papyrifera White birch	S-I	S	I-S	S	—
Calamagrostis canadensis Canada blue-joint grass	I	R	S	R	S
Carex spp. Sedges	S-I	R	S	—	S
Comptonia peregrina Sweet fern	S	I	I	—	—
Corylus cornuta Beaked hazel	S-I	S	I-R	S-I	—
Diervilla lonicera Bush honeysuckle	I	—	I	—	—
Epilobium angustifolium Fireweed	I	S-I	I-R	S	—
Poaceae Grasses	S-I	VR	S	R	S
Picea glauca White spruce	R	I-R	I-R	R	R
Picea mariana Black spruce	R	R	I-R	R	R
Pinus banksiana Jack pine	I-R	R	S	I	R
Pinus resinosa Red pine	R	R	VR	I	R
Pinus strobus White pine	I-R	R	I	I	I-R
Populus tremuloides Trembling aspen	S-I	S-I	S-I	S	—
Prunus pensylvanica Pin-cherry	S	S	I	S	—
Pteridium aquilinum Bracken fern	S-I	R	S-I	I-R	—
Quercus rubra Red oak	S	I-R	—	—	—
Ribes spp. Gooseberries/Currants	S-I	S	I	S	I-R
Rosa acicularis Prickly wild rose	S-I	R	I	S	R
Rubus idaeus var. *strigosus* Red raspberry	S-I	I-R	S	S	R
Salix spp. Willows	I	I-S	I	S	R
Vaccinium angustifolium Wild blueberry	S-I	S	VR	S	R
Viburnum spp. Wild raisin, Nannyberry	S	R	I	—	—

S Susceptible: These plants can be killed with one moderate application of the chemical when the treatment is normally applied.
S-I Susceptible to intermediate

I	Intermediate: These plants can be controlled with a high dosage
I-R	Intermediate to resistant
R	Resistant
VR	Very Resistant
—	No information

GROUND BROADCAST APPLICATION

Ground broadcast spraying using the Algonquin Air Blast Sprayer is the most common method of applying herbicides for chemical site preparation in shelterwood stands. This system uses a fan-produced air-stream to pick up the herbicide from the nozzles and deliver it to the target, producing very small droplets that can be deposited on both sides of the leaves, and that can reach vegetation behind obstructions. The most commonly used chemical is *Vision*®. Pronone, a granular formulation of hexazinone, can be applied using granular applicators (McLaughlan 1992). See Desrochers and Dunnigan (1991) for a comprehensive review of ground sprayers.

GROUND SELECTIVE APPLICATION

When herbicides are applied using backpack sprayers, they are sprayed in liquid solution directly onto the target vegetation from a tank carried by the operator. The spray solution can be applied in a broadcast format, selectively to specific target species, or limited to an area directly around crop trees. The method is limited to brush communities less than 2 m in height. *Vision*® is the most commonly used chemical, although the use of *Release*® is increasing.

When using spot-guns, herbicides are applied to the soil in a broadcast grid pattern or surrounding a particular target clump/individual. The equipment applies a precisely measured amount of chemical at each “spot”. Hexazinone can be applied using this technique as a liquid or as granules.

Basal spray treatments are done using backpack sprayers. The herbicide is applied to the bark of target stems near the base. It is an effective way to kill brush and small trees. It is very selective because the spray is directed at individual plants, but it is more time-consuming and laborious than foliage sprays (Bovey 1977). Care must be taken to make sure that herbicide does not splash onto advance regeneration. *Release*® or 2,4-D can be used. One advantage of this treatment is a wide range of seasons in which the chemical can be applied without losing efficacy.

Injection and cut/surface treatments are an effective way of controlling small to large trees. They can also be used on smaller stems following a brush saw operation. The herbicide can be applied in the active or dormant season. These methods are used to prevent sprouting from stumps and root suckering from tree species that are to be cut during a harvesting operation. For the cut- stump treatment, herbicide should be applied to a freshly cut surface (Bovey 1977).

7.3.2.3 Effects of herbicides on forest productivity, health and condition

It is important to remember that the effects of chemical site preparation on forest productivity, health and condition are dependent on site type and harvesting system used.

Chemical site preparation causes minimal disturbance to soil structure, organic matter, water movement (Boyd 1982; Cantrell 1985), downed woody material and standing leave-trees. Glyphosate and 2,4-D have no effect on forest floor decomposition rates at the recommended herbicide application rate (Fletcher and Freedman 1986).

Brand (1991) has found that chemical site preparation results in increased foliar nitrogen in crop tree seedlings, increased soil temperature, increased light intensity at the seedling level, and increased water availability to tree seedlings.

SOIL ORGANISMS

Increases in biomass on the soil surface from fallen leaves and in the soil from dead root materials following a herbicide application will increase the organic matter substrate available for plant and animal soil organisms. Populations of soil organisms will temporarily increase, but return to pre-treatment levels when the amount of easily decomposed organic material decreases (Krishka 1988).

WILDLIFE

All herbicides used in forestry on Ontario's Crown lands are registered under the Pest Control Products Act. The registration process is based on assessing the potential risks and benefits associated with the use of the product. A product is registered for use when the majority of the evidence available suggests that when used according to the label instructions the product will not pose any undue risk to people, wildlife or the environment. However, herbicides can indirectly affect wildlife by altering habitat (Newton and Cole 1996).

Soft mast (e.g. blueberry, cherries, serviceberries, raspberries) and hard mast (e.g. acorns, hazelnuts) are consumed by a large proportion of the wildlife species that inhabit conifer forests in Ontario (Naylor 1994). Soft and hard mast producing shrubs can be abundant on recently disturbed sites. Chemical treatments that affect these species can be modified to minimize impacts on mast production. For example, herbicides can be applied at the minimum concentration required to meet the timber objectives and unsprayed buffers could be retained around the edge of harvest blocks (Naylor 1994).

In the short term, herbicide treatments may reduce habitat for songbirds that prefer bushy deciduous cover and increase habitat for those who avoid bushy deciduous cover (Lautenschlager 1993). There may also be reduced use of sprayed areas by some species of small mammals and increased use by others, depending on their preferred habitat (Lautenschlager 1993). Chemical treatments can temporarily decrease browse and use by moose and deer for 1 to 4 growing seasons after treatment (Lautenschlager 1993). However, they may provide accessible browse for a longer period of time than if the area was not treated at all.

7.3.2.4 Planning a chemical site preparation operation

Planning for chemical site preparation requires a good analysis of vegetation and site conditions, clear objectives, and knowledge of the herbicide and application method that will be chosen. The *Herbicide Handbook* produced by Otchere-Boateng (1990) in British Columbia provides a good description of how to plan and implement a herbicide operation including tally sheets and a step-by-step procedure.

Planning for an aerial spray project begins one year before the application actually occurs. The process is very detailed and will not be explained in this guide. Please refer to *Aerial Spraying for Forest Management* (OMNR 1991) for more information.

7.3.2.5 Objectives of chemical site preparation

The main objective of chemical site preparation is to control competing vegetation. The objectives of the treatment should be quantified and should be stated by individual species or groups of plant species that are currently on the site or that will be stimulated to become established after the disturbance(s) (harvesting, mechanical site preparation and/or prescribed fire). TABLE 7.3.7 shows the relative resistance of different plant species to the five major herbicides available for forestry applications.

The choice of using chemical site preparation instead of tending depends on the relative tolerance of crop trees and competing vegetation to the different herbicides. If the intended crop species is not tolerant to the only herbicide or herbicide rate which will control the competing species, a chemical release may not be possible. If the site is a rich one, growth or even survival of the crop trees may be jeopardized if effective competition control is delayed. However, on a nutrient-poor site, chemical site preparation may not be required.

7.3.2.6 Selecting the site

When selecting a site for chemical site preparation, the following factors should be considered:

- Access: Unless aerial spraying is being considered, the logistics of moving people and equipment to the site at a reasonable cost during the scheduled season of treatment must be planned. Sites that will be logged in the winter may not have good road access in the summer or fall when a herbicide treatment is required. If planning an aerial spray operation, nearby staging areas will be needed.

- Topography: Steep slopes will constrain the area available for safe operation of ground spraying equipment.

- Wildlife values: Determine the value of the sites for wildlife and determine whether chemical site preparation will affect the quality of habitat.

- Sensitivity: Closeness to human habitation, water resources, etc.

- Overstory: Confirm the conifer component and other species that may seed-in or root sucker after a harvest operation or other disturbance. Examine both the overstory within the stand and the overstory of the neighbouring stands. Examine the size, distribution, species, and condition of residuals left on site to help in selecting which application method should be used.

- Understory: Establish the nature of the vegetation problem on the site. Examine the species, size, abundance, vigour and distribution of understory vegetation. Evaluate the expected impact of the vegetation. The autecology of the species on the site can help determine the type of herbicide and the method that should be used to control competing vegetation. The forest manager can also confirm the presence or absence of advance regeneration to help determine the timing of the operation. Examine succession in similar stands in the vicinity that have already been harvested to observe the vegetation that has developed. The choice of herbicide will depend on whether the purpose of the treatment is to control existing vegetation (glyphosate, triclopyr, 2,4-D) and/or to prevent germination (hexazinone). Hexazinone is also effective in controlling raspberry.

- Previous activities on the site: If harvesting or mechanical site preparation have already occurred, determine the time and method used. For example, winter harvest and light mechanical site preparation will not have stimulated the seedbank and will not have provided seedbeds for seed rain as much as summer harvesting and deeper mechanical site preparation.

- Slash: Distribution, size, and decomposition class of logging slash and other debris that may prove to be impediments to the chosen method of application.

- Soils: Determine the soil type, as some herbicides (e.g. hexazinone) are restricted to specific soils.

7.3.2.7 Selecting the herbicide, application method and timing

Specific criteria that help choose application method and herbicide to be used are: objectives, silvicultural system, timing during the system, environmental considerations, cost, and equipment availability. Some operational considerations that should be evaluated are:

- Herbicide: The herbicide that is chosen will depend mostly on target species, method of application, crop species, and site conditions (TABLES 7.3.4, 7.3.5 and 7.3.7).

- Rates: Rates are limited to the range listed on the product label. Target and crop species susceptibility, as well as the density of competing vegetation will, help determine whether to use higher or lower rates.

- Pre-harvest treatments: Overstory species that produce abundant root suckers after a harvest operation (e.g. trembling aspen) can be controlled before harvest using single stem treatments. Other species that will produce abundant seed and/or provide unnecessary shade, but will not be cut during the harvesting operation (e.g. small diameter red maple) can also be treated.

- Broadcast *vs*. selective: Broadcast treatments are normally done on areas that are nutrient-rich and where a continuous distribution of vegetation is expected to develop after disturbance. Selective treatments are useful on less competition-prone or sensitive sites, where individual stems or areas can be treated around spots that are targeted for regeneration.

- Timing: Soil active herbicides are most effective when applied in the spring, as soon as possible after the ground thaws. Triclopyr and 2,4-D are most effective immediately after full leaf out. Glyphosate tends to most effective during flower and fruit maturation. TABLE 7.3.6 provides timing information for some vegetation categories and selected herbicides. Foliar sprays should be delayed for one growing season after a harvest and/or mechanical site preparation treatment to allow time for seeds to germinate and for sprouts and root suckers to develop. Soil active herbicides are most effective when applied as soon as the ground settles after a soil disturbance.

7.3.2.8 Assessing the effects of treatment

Assessing the treatment effects includes both assessing the quality of application and treatment efficacy. They can be assessed when the effects of the herbicide become apparent: 2 to 3 weeks after application of 2,4-D and triclopyr, 3 to 4 weeks after hexazinone treatments, and when plants start to leaf out the spring after application with glyphosate.

The quality of the application involves looking for skips, overlaps, and drift. Herbicide efficacy is assessed by looking at the control of target plants. To obtain meaningful information, an untreated control plot should be established for comparative purposes.

Assessment methodology is described in Otchere-Boateng (1990).

7.3.2.9 Ecosite specific considerations

Based on general characteristics of ecosites, a knowledge of autecology of both crop and non-crop vegetation and the effect of different herbicides and their application methods, management interpretations can be developed to help prescribe site preparation treatments, in this case, chemical site preparation. However, each site should be examined to determine local conditions, which may not be the same as the average ecosite condition.

Interpretations for northwestern or northeastern Ontario ecosites or site types can be made by examining the ecosite equivalency table (TABLE 3.0.3) in Section 3.0 "Characteristics of the Great Lakes-St. Lawrence Conifer Forest" and using information presented in this guide on autecology of both crop and non-crop vegetation (***see*** Section 3.4.7 "Autecology of Associated Species") and use of chemical site preparation (described earlier in this section).

Central Ontario ES 11.1, 11.2, 12.1, 12.2, 13.1, 13.2

These ecosites have low levels of conifer and hardwood regeneration. They have between 10 to 15 per cent cover balsam fir, 10 to 15 per cent cover red maple and 10 to 20 per cent cover hardwood shrubs (beaked hazel is most common species) in the understory. These ecosites are not likely to require a broadcast chemical site preparation treatment. Balsam fir can be cut or knocked over during the harvest operation. If local site conditions show high levels of balsam fir, a mechanical site preparation treatment may be required. Selective herbicide treatments can be used to control red maple and beaked hazel competition, but care should be taken not to damage advance white pine regeneration. Pre-harvest treatment of trembling aspen can be used in ecosites 13.1 and 13.2. Most soils in this group of ecosites are coarse, especially the “x.1” types. Hexazinone should not be used on coarse soils.

Central Ontario ES 14.1, 14.2

These ecosites have moderate levels of conifer and hardwood regeneration and can be considered for a chemical site preparation treatment. They have between 5 to 10 per cent cover balsam fir, up to 30 per cent cover red maple, red oak and hard maple and between 15 to 20 per cent cover hardwood shrubs (beaked hazel most common species) in the understory. Ground sprayers can be used, but be aware of slopes on these ecosites. Over 80 per cent of the sites are on slopes, with over 50 per cent being on the upper slope position. Some soils in this group of ecosites are coarse, especially “x.1” types. Hexazinone should not be used on coarse soils. Soils are less coarse in the ES 14.2 group. Areas with advanced red oak regeneration can be identified and protected. Trembling and largetooth aspen may produce root suckers following logging and can be treated using pre-harvest stem treatments.

Central Ontario ES 16.1

Pre-harvest chemical site preparation is not likely to be required on this ecosite.

Central Ontario ES 17.1, 17.2, 18.1, 18.2, 19.1, 19.2

These ecosites have moderate to high levels of hardwood regeneration (red maple, trembling aspen, white birch, and sugar maple) and tall hardwood shrubs (beaked hazel, mountain maple) and high levels of herbs. They are good candidates for chemical site preparation. Ground sprayers can be used, but be aware of slopes on ES 17.1, 17.2 and 19.1, 19.2. Over 60 per cent of the sites are on slopes, with over 25 per cent being on the upper slope position. Pre-harvest stem treatment of trembling aspen and largetooth aspen can be used to prevent root suckering. Type “x.2” ecosites are likely to have quicker recovery of understory vegetation following harvest and therefore, are more likely to require chemical site preparation.

Central Ontario ES 20.1, 20.2

These ecosites have moderate levels of conifer and hardwood regeneration. They have between 20 to 25 per cent cover balsam fir, up to 15 per cent cover red maple and between 30 to 35 per cent cover hardwood shrubs (beaked hazel and mountain maple most common species) in the understory. These ecosites can be considered for chemical site preparation. Balsam fir can be cut or knocked over during harvest. If local site conditions show high levels of balsam fir, a mechanical site preparation treatment may be required. Ground sprayers can be used to control hardwoods and tall shrubs, but be aware of slopes on these ecosites. Over 70 per cent of the sites are on slopes, with over 30 per cent being on the upper slope position. Most soils in this group of ecosites are coarse, especially “x.1” types. Hexazinone should not be used on coarse soils. Duff layers are thicker and soils are less coarse in the ES 20.2 group. Pre-harvest stem treatment of trembling aspen can be used to prevent root suckering. Type “x.2” ecosites are likely to have quicker recovery of understory vegetation following harvest and therefore, are more likely to require chemical site preparation.

Central Ontario ES 21.1, 21.2

These ecosites have moderate levels of conifer and hardwood regeneration and can be considered for a chemical site preparation treatment. They have 15 to 20 per cent cover balsam fir, up to 10 per cent cover red maple and white birch, and 10 to 20 per cent cover hardwood shrubs (beaked hazel and mountain maple most common) in the understory. Balsam fir can be cut or knocked over during harvest. If local site conditions show high levels of balsam fir, a mechanical site preparation treatment may be required. Ground sprayers can be used to control hardwoods and tall shrubs, but be aware of slopes on these ecosites, especially on ES 21.1 where over 85 per cent of the sites are on slopes, with almost 50 per cent on upper slopes. Some soils in this group of ecosites are coarse where hexazinone should not be used. There are areas of wet organic soils in ES 21.2 that should be avoided when planning a chemical site preparation treatment.

Central Ontario ES 30.1, 30.2

Although these ecosites have low levels of hardwood regeneration, they have up to 15 per cent cover of shrubs and herbs of which striped maple, mountain maple, and beaked hazel are common species. Disturbance from logging and mechanical site preparation may increase the cover of these species and may stimulate the seedbank. Chemical site preparation may be required. Ground sprayers can be used, but be aware of slopes on these ecosites. Over 70 per cent of the sites are on slopes, with over 25 per cent being on upper slope positions.

Central Ontario ES 32

These ecosites are dominated by wet organic soils with some fresh to very moist mineral soils.

Central Ontario ES 22, 33

These ecosites have moderate levels of conifer, low levels of hardwood regeneration (mainly red maple) and moderate levels of tall shrubs (mainly mountain maple). They have between 10 per cent and 15 per cent cover balsam fir in the understory. These ecosites are not likely to require a broadcast chemical site preparation treatment. Balsam fir can be cut or knocked over during harvest. If local site conditions show high levels of balsam fir, a mechanical site preparation treatment may be required. Selective herbicide treatments can be used to control red maple and mountain maple competition. Care should be taken not to damage advance cedar and white spruce regeneration. There may be areas of advance yellow birch regeneration on ES 33 that can also be identified and protected.

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7.3.3 Prescribed Fire

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Prescribed fire has been defined as "fire applied in a knowledgeable manner to forest fuels on a specific land area under selected weather conditions to accomplish predetermined, well-defined management objectives" (Wade and Lunsford 1989). Prescribed fire in the Great Lakes-St. Lawrence conifer forest can be used either pre-harvest or post-harvest. Pre-harvest burning is applied to prepare a receptive seedbed and control competing vegetation in an attempt to establish regeneration before a partial cut. Post-harvest prescribed fire is applied on sites managed under the clearcut system, where residual overstory trees are not required to be alive after the fire. These sites are usually regenerated using assisted regeneration either by planting or seeding.

Many Great Lakes-St. Lawrence conifer ecosystems were affected by fire in the past. In fact, several species were dependent on fire for their renewal and maintenance. According to Heinselman (1981) fire regimes in the Great Lakes-St. Lawrence forest were characterized by 1) short cycle crown fires in the near-boreal jack pine, black spruce, and white spruce-mixedwood forests and, 2) combinations of moderate-intensity short-interval surface fires and small scale crown fires at longer intervals in the red-white pine forest. Fire regimes in northern hardwood-pine-spruce-fir forests, which include white pine, hemlock, white and red spruce, balsam fir and white cedar are not well documented, but are thought to have been severe surface fires that occurred only after a prolonged drought. These fires probably occurred in forests that were breaking up due to wind or ice storm damage, or insect attacks. Low-intensity long-interval surface fires may also have occurred in these forest types (Heinselman 1981). By understanding fire intensity and fire effects of natural fires in conifer forests of the Great Lakes-St. Lawrence forest region, prescriptions can be developed for using prescribed fire to successfully regenerate these species.

The role of fire in perpetuating hemlock, cedar, and red spruce is poorly documented. However, based on the silvics of these species and information contained in the literature, prescribed burning appears to be a tool that can be used in some cases. In contrast, the role of fire in perpetuating white and red pine is well documented (Heinselman 1981; Day and Carter 1990; Maissurow 1935) and reviewed (Van Wagner 1993). Most old pine stands in the Great Lakes-St. Lawrence forest contain many trees showing basal fire scars, indicating their tolerance of and association with fire.

Natural fires in white and red pine ecosystems are generally of moderate rather than high intensity (Van Wagner 1993) and commonly run through the understory. They often scorch the crowns of some mature white and red pine (Van Wagner 1963; Methven 1971; Methven 1973; Van Wagner and Methven 1978), but leave many thick-barked trees to re-seed the stand (Ahlgren 1959, 1960,1976; Ahlgren and Ahlgren 1960). On mesic sites, in the absence of fire, balsam fir, red maple and beaked hazel become so dense that white and red pine seedlings cannot become established or if they do become established, they do not recruit to form a new stand (Day and Carter 1990).

When red and white pine are about 80 years old, they share characteristics that enable them to resist damage or death by light-to-moderate intensity fires (Van Wagner 1971). These characteristics include: 1) thick bark giving them resistance to girdling by fire, and 2) great height, that places their crowns out of reach from low to moderate intensity ground fires. In instances when the lower part of the crown is scorched from the convective heat of ground fires, they are able to survive. In fact, red and white pine can withstand 85 per cent crown scorch before significant mortality occurs (Van Wagner 1963; Methven 1971). Mortality is influenced by the season of burning. Severe crown scorch from early spring burns result in less mortality because buds have not yet flushed and bud scales protect the current year's needles from the heat of the fire (McRae *et al.* 1994).

White pine and red pine can regenerate abundantly after a wildfire provided that mature trees of seed-bearing age survive the fire and a seed year corresponds with it (Ahlgren 1976, 1960, 1959; Ahlgren and Ahlgren 1960). Red pine requires a higher degree of canopy opening than white pine, and is most likely to regenerate on dry rocky upland and ridge sites (Day and Carter 1990). Considering periodicity of seed years between red and white pine, wildfires are more likely to correspond with a white pine seed year than with a red pine seed year.

Pre-harvest understory prescribed fire

Pre-harvest prescribed fires are usually low- intensity burns that move through the understory of a stand.

The use of understory prescribed fire for the natural regeneration of white and red pine has been investigated on an experimental and operational basis in Petawawa, Ontario (Van Wagner and Methven 1978), other parts of Ontario (e.g. North Bay, Pembroke, Blind River, and northwestern Ontario), Minnesota (Buckman 1964), and New Hampshire (Olson and Weyrick 1987). However, it has not been used extensively as an operational tool in Ontario. There has been considerably less experience using pre-harvest burning for the management of other conifer species. Some authors suggest that pre-harvest prescribed fire could be used to prepare seedbeds and control competing vegetation in ecosites containing hemlock (Godman *no date*; Anderson *et al.* 1990). There is evidence that pre-harvest prescribed fire can be used to promote natural regeneration of white spruce when it appears in red and white pine dominated stands that are managed using the shelterwood system. White spruce can benefit from seedbeds produced as a result of pre-harvest burning. Light understory burns will damage small diameter spruce, but many seed producers will survive. White spruce does not have the same thick fire-resistant bark as do red and white pine, and is therefore more susceptible to moderate intensity fires.

Natural understory fire creates the following conditions that enable white and red pine, white spruce, and hemlock to establish a new age class:

- control of low-level competing vegetation
- reduction of duff layer to prepare seedbed

- opening of the overhead canopy

- a live overhead or nearby seed source.

In forest management, these conditions can be created using a combination of prescribed fire and the appropriate silvicultural system. An understory prescribed fire can be used to accomplish seedbed preparation, by reducing the L and some of the F layers of the duff (not mineral soil exposure), and competition control, by top-killing understory hardwood trees and brush and killing understory balsam fir. Because an overstory seed source is needed, the fires must be burned under standing crop trees and should be of low enough intensity to avoid killing the overstory trees, although some mortality is inevitable where accumulations of dead woody material are present under large crop trees. The final requirement, some degree of canopy opening, is accomplished by a partial cut (Van Wagner 1993). The burn should occur in a good seed year to maximize the chances for successful natural regeneration.

Pre-harvest understory fires are of light intensity with flame heights between 50 and 100 cm and a frontal fire intensity of 400 to 600 kW/m (Van Wagner and Methven 1978; Van Wagner 1993). This type of fire will kill balsam fir from 3 to 15 cm in basal diameter (Methven 1971) and the above ground portion of hardwood shrubs and trees up to 8 cm in diameter (personal observation), depending on the local fire intensity and stand conditions. Although the conifer understory is easily killed by fire, hardwood trees and shrubs re-sprout. Some species sprout more vigorously than others. Hazel is a very vigourous sprouter and can only be reduced by repeated summer burns (Van Wagner 1963; Buckman 1964). Basswood, red oak, and white birch are vigourous sprouters while elm, bur oak, ironwood, and red maple are slightly less vigourous (Perela 1974). The least vigourous sprouters are sugar maple, beech and yellow birch (Perela 1974). Because most hardwood shrubs and trees sprout after a fire, a second fire or a follow-up chemical or manual treatment may be required to adequately control hardwoods in stands with a high cover of these species (Van Wagner 1963; Buckman 1964; McRae *et al.*1994).

Burning stimulates germination of buried seed, so that some species become very numerous after a fire when they were barely noticeable on a site before (Ahlgren 1979; Abrams and Dickmann 1984). For example, blackberry, raspberry, field bindweed, and pin cherry tend to increase in abundance after a low to moderate intensity fire (Dickmann 1993).

Pre-harvest understory fires are normally conducted in the spring for several reasons:

1) When fire occurs in the spring before the new growth flushes, the tree may survive even 100 per cent crown scorch. Buds, protected by bud scales, may survive heat that kills the over-wintering needles (McRae *et al.* 1994).

2) The duff layer is still moist in the spring and will protect overstory tree roots from damage.

3) Mesic sites will not ignite after green-up except under severe fire weather indices. Burning under high indices will likely result in unacceptable crown damage to overstory trees.

White pine is far easier to regenerate using pre-harvest prescribed fire than red pine. Even when the original stand is more than half red pine, pine regeneration after fire was typically white pine (Van Wagner 1993).

Post-harvest prescribed burning

Post-harvest prescribed fire after a clearcut can be used with artificial regeneration in areas where there is an insufficient conifer component for a shelterwood or seed tree cut. For use of post-harvest prescribed burning for natural regeneration of jack pine or black spruce, refer to "*A Silvicultural Guide to managing for black spruce, jack pine and aspen on borealf orest ecosites in Ontario*".

The primary objective of post-harvest prescribed burning in clearcuts is to reduce the amount of harvesting debris or slash from the site to create suitable planting spots and improve planter access. It can also be used to control some species of competing vegetation. By using prescribed burning, windrowing or piling of slash can be avoided. Windrows and slash piles create long-term access problems, fire hazards and reduced area for regeneration. Prescribed fires also increase the amount of available nutrients that can be used by plants on the site. However, this effect is temporary and crop trees should be planted as soon as possible after the fire to benefit from the increased availability of nutrients on the site, before the nutrient flush is captured by competing vegetation.

Post-harvest burning could be used to create good conditions for cedar regeneration by:

1) reducing slash loads (habitat for hares that damage regenerating cedar)

2) removing undecomposed mosses in swamps

3) increasing soil temperatures and pH, and

4) controlling competing vegetation (Miller 1992).

Experience in using prescribed fire for cedar management is limited, but initial results indicate that is a promising technique (McLeod 1992; Miller 1992). The main impediment to using prescribed fire on cedar ecosites is that the burning window is very small. Typical cedar ecosites are very wet for most of the growing season.

Post-harvest prescribed fire after a seed tree cut or a shelterwood cut to promote natural regeneration of white and red pine is not recommended. There is insufficient experience and knowledge available to derive a prescription to succeed in meeting objectives. The fire may be able to achieve the seedbed preparation objective, but it will likely not meet vegetation control or overstory damage objectives. Slash on the site will promote a more intense fire and will contribute to excessive mortality of the overstory. If slash is allowed to break down by waiting several years after the cut, vegetation will be extremely vigourous and sprouting after the burn will be excessive.

7.3.3.1 Effects of prescribed burning on forest productivity, health and condition

For an excellent review of the effects of understory prescribed fire, please refer to Dickmann (1993). Although reviews dealing with fire effects on clear-cut sites are not specific to the Great Lakes-St. Lawrence forest, many of the principles are applicable. Refer to Ahlgren and Ahlgren (1965), Archibald and Baker (1989), Chrosciewicz (1974, 1988), Grier *et al.* (1989), Sims (1976), and Wells *et al.* (1979) for more information. It is important to remember that the effects of prescribed burning on forest productivity, health and condition are dependant on site type and harvest system used, especially in the case of slash burns. Different harvesting systems and operations will result in different fuel loading, soil compaction and disturbance, species and density of ground vegetation, as well as erosion potential.

SOILS, WATER, NUTRIENTS

Light-intensity fires carried out in the spring have little effect on organic matter (Methven and Murray 1974), soil nutrients, soil structure, sedimentation, water quality, and water movement (Dickmann 1993). In the short term, light-intensity burns stimulate micro-organisms responsible for N-fixation and N-mineralization because organic inhibitors are consumed, pH and soil temperature is increased, and cations are released (Ahlgren 1974; Dickmann 1993). In some cases, even repeated light burns do not have an adverse effect on soil nutrients. For example, Lunt (1950) found that soil pH, total N, and available P and Ca were higher in burned than in unburned plots after annual burns for 20 years under red and white pine stands in Connecticut. Alban (1977) found that burning in a 90 year old red pine stand in Minnesota reduced the organic matter and nutrients in the forest floor, but that nutrient levels increased in the mineral soil. Several studies have shown that nutrients and organic matter shift from the forest floor to mineral soil after burning (Dickmann 1993).

Frequent burning or high severity burns may reduce fertility in sandy or gravelly, low-fertility sites (Bell and Binkley 1989; Christensen 1977; Chrosciewicz 1990). Summer burns can have an negative effect on forest productivity if they remove more than half the organic matter (Alban 1977). Some nutrients stored in woody plants, litter and duff are released as gases during burning and additional nutrients may be drained from ashes by subsequent rainfall. Increased fire intensity will increase the severity of this nutrient loss (Dickmann 1993; Herr *et al.* 1994). In clay soils, when there is complete removal of organic matter, compaction by raindrops can lead to pudding, where the soil surface becomes impermeable. This can lead to rooting difficulties in planted seedlings (Chrosciewicz 1990).

SOIL ORGANISMS

In some cases, fire may increase formation of ectomycorrhizae on white pine roots and increase white and red pine planted seedling survival and health (Herr *et al.* 1994). Soil litter consumed by fire may reduce food supplies and moisture for soil fauna (Dickmann 1993). Worm and arthropod populations temporarily decline following fire (Dickmann 1993). Diversity and number of carabid beetles may increase after a burn (Duchesne and McAlpine 1993). Generally, soil micro flora and fauna populations are temporarily reduced, but quickly re-colonize at increased population levels.

WILDLIFE

Very little data, if any, has been collected on the effects of prescribed burning on wildlife in the Great Lakes-St. Lawrence forest. However, effects of fire on wildlife populations and their habitat are well documented in other ecosystems.

Prescribed fire has very little direct effects on wildlife (mortality) except for non-mobile stages (e.g. nests). The direct effects can be minimized by modifying the timing of burns.

Available browse for large ungulates may be temporarily reduced but then may be increased for the next few years. Light-intensity fires top-kill understory hardwood trees and shrubs that have grown out of reach of browsing animals and stimulate sprouting, thus increasing their quantity and availability (Brender and Cooper 1968; Perela 1974; Olson and Weyrick 1987; Dickmann 1993).

Habitat for several wildlife species is often improved as a result of increased growth of grasses, herbs and forbs (Horne 1938; Storer 1932), increased production of fruit and seed by grasses, herbs and shrubs (Ahlgren and Ahlgren 1960), and more low cover (Dickmann 1993). For example, bluebirds, kestrels and meadow voles prefer open, grass/herb habitats.

It is well documented that the quality of browse and forage after a fire increase: higher protein levels, higher mineral content, and improved digestibility (DeWitt and Derby 1955; Lay 1957; Grelen and Epps 1967; Dills 1970; Pearson *et al.* 1972; Kirk *et al.* 1974; Lewis *et al.* 1982; Hobbs and Spowart 1984; Thill *et al.* 1987). This effect was temporary and more pronounced with high intensity fires than with lower intensity fires (DeWitt and Derby 1955).

Prescribed fire may affect the supply of down woody debris (DWD) for wildlife. If hot enough, prescribed fires may consume small diameter DWD and may char large diameter DWD (Naylor 1994). Charred DWD is generally less suitable as wildlife habitat because 1) the bark is removed (eliminating habitat for many invertebrates) and 2) charring may result in case hardening that slows the rate of decomposition and essentially eliminates logs as burrows for small wildlife (Maser *et al.* 1979; Naylor 1994).

WILDFIRE HAZARD

Prescribed burns reduce forest fuels, thus reducing the potential for a future high-intensity wildfire.

PESTS AND DISEASES

Populations of some insect pests of white and red pine such as the red pine cone beetle (Miller 1978) and the white pine cone beetle (Wade *et al.* 1989) can be reduced following a fire.

HEALTH OF RESIDUALS

Fire injury may introduce insects and/or disease into a stand (Olson and Weyrick 1987). Advanced regeneration may be damaged or killed. However, light intensity understory burns do not adversely affect overstory tree growth, provided that crown scorch is limited (Alban 1977; Methven and Murray 1974).

Hot summer fires can cause smouldering in duff and injury to root collars and fine feeder roots of overstory trees (Dickmann 1993; Olson and Weyrick 1987). Cool spring fires that only consume the top litter layer probably do not affect fine roots (Dickmann 1993).

AIR QUALITY

Smoke from prescribed burning may reduce air quality, visibility and can affect the health of workers and the public. Smoke management practices should be implemented based on information in a publication by the Ontario Ministry of Natural Resources (OMNR 1992). Efforts should be directed at reducing the amount of smoke created and directing smoke away from communities and roadways. Smoke concerns are much less in the case of a light intensity understory burn (Dickmann 1993).

7.3.3.2 Objectives of prescribed burning

Forest managers can use prescribed burning to attain a variety of objectives. Categories under which specific objectives can be stated are:

- preparing a site for natural and/or artificial regeneration
- promoting the growth of a particular species
- restoring and/or maintaining ecosystem processes and/or functions
- controlling insect pests or diseases
- controlling vegetation
- improving and/or developing wildlife habitat
- producing and obtaining research information
- developing and/or testing operational techniques
- training staff

- reducing wildfire hazard.

For each site, more detailed, quantified objectives must be established so that effectiveness of the treatment can be monitored.

7.3.3.3 Planning a prescribed burn

The *Prescribed Burn Planning Manual* (OMNR 1996) describes the planning process, content of an operational plan, and process for public input and review into the plan. This manual should be reviewed when considering prescribed burning as a site preparation treatment. The publication *Forest Manager's Guide to Prescribed Burn Planning* (Wearn *et al.* 1982) can also be useful to help visualize the effects of burns on different site types under different burning conditions.

7.3.3.4 The Canadian Fire Weather Index System

Fire weather and fuel moisture conditions necessary to achieve prescribed fire objectives must be described in terms of the Canadian Forest Fire Weather Index System (CFS 1987). The Fire Weather Index (FWI) System is composed of six components that reflect fuel moisture and fire behavior. The system depends solely on weather readings taken each day at 13:00 hours: temperature, relative humidity, wind speed, and rainfall during the past 24 hours. For some codes, the current month must be specified. A weather station that is used to collect data to generate indices must be as close to the burn site as possible and should be in a forest opening. Although FWI is calculated using weather variables taken at 13:00, it actually represents fire danger at the mid-afternoon period of highest fire intensity (17:00 hours).

- Fine Fuel Moisture Code (FFMC) represents the moisture content of litter (nominal depth 1.2 cm) and other cured fine fuels in a forest stand. Several daily weather measurements (taken at 13:00) are required to calculate the code: temperature, humidity, wind, and rain (during last 24 hours).

- Duff Moisture Code (DMC) represents the moisture content of loosely compacted, decomposing organic matter (nominal depth 7 cm) and the larger fine fuels. Daily weather measurements used to calculate this code are: temperature, humidity, rain and the month.

- Drought Code (DC) represents a deep layer of compact organic matter (nominal depth 18 cm), down decayed logs, and large slash fuels. It is not as important to understory burning as the other two moisture codes because deep duff has not had a chance to dry out in early spring when these burns are usually performed. However, it does become important for summer burns. It is calculated using daily measurements of temperature, rain, and month.

- Initial Spread Index (ISI) is a combination of wind and FFMC that represents the rate of spread alone, without the influence of variable quantities of fuel, aspect or topography.

- Build Up Index (BUI) is a combination of the DMC and the DC that represents total fuel available to the spreading fire. It is used to calculate slash consumption and depth of burn values.

- Fire Weather Index (FWI) is a combination of the ISI and the BUI that represents intensity of the spreading fire as energy output rate per unit length of fire front.

The prescribed burn prescription will list season and range of indices required for the burn to meet desired objectives and will be developed using the most common or important fuel complex on the site.

7.3.3.5 Pre-harvest understory burning

Pre-harvest prescribed burning has been tried on a limited basis in Ontario, mostly in white and red pine stands. It has been shown to be feasible on small areas (<30 ha in size). Usually, back fires are used and are ignited manually with drip torches in the spring when understory vegetation is just beginning to leaf out. Flame heights are less than 1 m and fire spreads at less than 1 m per minute, on average. Fire behaviour is affected by ignition pattern and intensity is greatly increased by converging flame fronts.

Pre-harvest prescribed fire provides short-term control of understory hardwood stems (reducing their height and percent ground cover), longer term control of small (<3 m in height) balsam fir and other conifers, and provides a suitable seedbed for white pine and red pine, while minimizing damage to overstory trees. Prescribed burning should be conducted in a good seed year and followed by a partial harvest when regeneration is established. For a good description of the operational aspects of understory prescribed burning in white and red pine stands, refer to McRae *et al.* (1994).

SELECTING THE SITE

When selecting a site for pre-harvest prescribed burning, the following factors should be considered:

- Stands must be good candidates for natural regeneration.

- Greater than 80 years old: White and red pine trees must have plated or thick bark, so that they will resist cambial damage from the heat of the fire. Sometimes this occurs on younger trees (Olson and Weyrick 1987), and can be field verified if stands <80 years old are being considered.

- Access: Must be adequate to move people, fuel and equipment at a reasonable cost.

- Values: Check for values that may need to be protected or where people must be notified about the prescribed fire.

- Boundaries: Good natural boundaries (low, wet area in spring, creek, river) reduce the complexity and cost of a burn.

- Water sources: A good water source for suppression. Can be as small as a creek or pond, but its suitability should be checked if it is likely to be seasonal.

- Overstory - height to live crown: This will help determine the maximum fire intensity that will be permitted to avoid excessive crown scorch. The height to live crown is used as an input into Van Wagner's (1973) crown scorch model to help fire personnel determine the relationship between fire intensity and potential crown scorch.

- Understory - size and distribution of balsam fir: Used to assess the difficulty of burning and the potential control of balsam fir by the fire. A continuous cover of balsam fir in the understory will take longer to dry out in the spring and may require the higher end of the range of indices or a pre-burn treatment for adequate fire spread. Clumps of balsam fir with branches that reach the ground may torch at the high end of the range of indices and damage overstory crop trees above them.

- Understory - distribution/species of shrubs and hardwood regeneration: Used to assess competitiveness of site and potential for the need for two burns or a follow-up chemical/manual tending treatment.

- Presence of advanced regeneration: If there is a large number of advanced crop tree regeneration, the use of fire may be undesirable.

- Pole-sized crop trees will likely be damaged or killed.

- Pulpwood component will be blackened at the base, thus making it unsuitable for pulp without treatment. Other markets may need to be found.

- Topography and slope: Used to assess difficulty of burning, layout of ignition lines, and potential scorch damage to overstory trees.

- Size of area: Will affect resources needed for the burn and the burn cost.

- Soils: Once the site has been classified in terms of ecosite, the forest manager will know the range of soil parameters that are common within that ecosite. Important parameters to indicate potential for re-vegetation are moisture regime and texture. Organic matter depth is also important. It will be difficult to create a good seedbed if duff layer is >10 cm deep.

DETAILED FUEL DESCRIPTION

Fire behaviour on a burn is determined in part by availability and types of fuel within the burn boundary. A detailed description of fuel complexes on site must be recorded. Depth, arrangement and continuity for fuel complexes should be characterized using *Measurement and Description of Fuels and Fire Behaviour on Prescribed Burns: A Handbook* (McRae *et al.* 1979). Fuel complexes should be defined in terms of:

- forest floor cover (needle litter, grass, hardwood leaf litter, moss cover)
- organic layer (duff)
- surface fuels (herbaceous cover, down woody debris)
- ladder fuels (low, tall, dead, living)
- stand structure (stocking, crown closure, height to live crown).

If there is a significant amount of down woody material on site, fuel loading plots should be established. Pre-burn sampling quantifies the initial loading and depth of fuels, which aids in prescription setting. Sampling methods presented in McRae *et al.* (1979) are commonly used in Ontario.

SETTING OBJECTIVES

Objectives for an understory prescribed burn must be measurable. An example of objectives used in previous burns are:

- remove litter layer to provide good seedbed
- mortality of 90 to 100 per cent in understory balsam fir
- mortality of 80 to 100 per cent in above-ground stems of understory hardwood shrubs and trees
- mortality of overstory trees must be less than 15 per cent.

TIMING THE BURN

The best time to perform a pre-harvest understory prescribed burn is in the spring before full leaf-out of understory herbaceous plants. Duff under the surface leaf layer is still moist, thus preventing a smouldering fire that could damage overstory tree roots. If the burn occurs after the beginning of leaf flush in hardwood trees and shrubs, they will have less carbohydrates in the roots for sprouting. However, the burn should be conducted as soon as the required indices are reached because of the short window of opportunity between snow melt and herbaceous leaf flush. Once leaf flush in the herbaceous layer has occurred, fire spread is impeded.

Ideally, the burn (or the last burn, in the case of multiple burns) should occur in a good seed year. The freshly prepared seedbed will be available for germination and the delay between the prescribed fire and harvest will be minimized.

SETTING THE PRESCRIPTION

A typical prescription for a spring understory prescribed burn in a white pine stand that has mainly red and white pine needle litter as fuel (C5 fuel type) would be as follows:

- FFMC 88 to 94
- DMC >20
- ISI 3 to 11

These indices are the most important ones for spring understory burns. Some plans list the RH, but this will be reflected in the FFMC.

Season and prescription (range of indices) can be imputed into the PBWX computer program (Martell 1978) to calculate the probability of that prescription occurring and the expected number of days that the prescription will occur for the prescribed burn site.

FIRE BEHAVIOUR PREDICTION

Fire behaviour can be predicted for both low and high ends of the prescription range using the "Canadian Forest Fire Danger Rating System" (CFFDRS). Predictions can be made for each fuel type present on the site. Fire behaviour variables that can be analyzed include: rate of spread (maximum/minimum), fuel consumption (kg/m^2), spotting distance, and frontal fire intensity (kW/m). Rates of spread can be adjusted using the Canadian Forest Fire Behaviour Prediction System.

ASSESSING THE EFFECTS OF THE BURN

It is important to assess whether the treatment met objectives for two reasons: 1) to determine if results were as expected, and 2) to document results as a learning experience which will assist in planning future treatments.

Critical factors that need to be measured to assess the success of an understory burn are:

- fuel: pre-burn and post-burn depth of duff and slash loading using the line-intercept method

  - rates of spread
- fire intensity calculation

- effect on residual trees, including:

  - stem charring
  - girdling
  - crown scorch - height
  - crown scorch per cent
  - mortality.

- Understory shrub and tree assessment, including:

  - pre-burn and post-burn number of species present
  - number/ m^2
  - height
  - per cent cover.

- Herb layer assessment, including:

  - pre-burn and post-burn number of species present
  - frequency.

See Van Wagner (1993) for a discussion on data that should be collected. An example of the plot that could be established for long-term monitoring is described in *Fire Monitoring Handbook* (USDI 1992) produced by the United States National Park System.

7.3.3.6 Post-harvest burns

The purpose for prescribed burning after harvest is to reduce woody debris, create sites for natural or artificial regeneration, reduce depth of organic matter, “set back” unwanted vegetation and improve planting crew access. Information and research is still needed on how to burn under a residual forest canopy after harvest without causing undue damage to overstory trees.

Post-harvest burns usually involve broadcast burning of material scattered over an open area such as a clearcut. They can be ignited manually using hand-held drip torches or aerially using helitorches or the Ontario Aerial Ignition Device (OAID). Helitorches are devices suspended from a helicopter that drip flaming jellied fuel. The OAID also ignites fire from a helicopter, but drops small hollow plastic spheres (resembling ping-pong balls) filled with potassium permanganate crystals that have been injected with ethylene glycol. A delay of 10 to 20 seconds occurs between injection and ignition of the balls. For more information on the Helitorch and OAID dispenser, please consult the *Specialized Fire Equipment Manual* (OMNR 1989).

Aerial ignition is used to ignite a large area or when ignition by workers on foot is not safe. It is the best method for igniting convection type burns. Convection columns can be produced with either the OAID or helitorch using various ignition patterns including centre fire and strip head fires. *Centre firing* is done by lighting the fire in the centre of the burn block and then lighting concentric rings of fire around the centre until the perimeter is reached. A strong convection column is established that produces an indraft that draws the concentric ignition lines toward it. *Strip head fires* are accomplished by using a combination of backfires and headfires. A fire is called a "headfire" if it runs with the wind or up a slope. If it runs down a slope or against the wind, it is called a "backfire". Normally, strip head fires are started against the leeside boundary with the use of a backfire with subsequent headfire ignition lines progressing at a right angle to the wind. The intensity of these subsequent lines will draw the initial ignition line away from the boundary. Wind speed should be less than 15 km/hr for convection burns. When winds are more than 15 kph, the convection column will remain bent over the leeside boundary.

SELECTING THE SITE

When selecting a site for post-harvest prescribed burning, the following factors should be considered:

- access: must be adequate to move people, fuel and equipment at a reasonable cost
- values: check for buildings or other structures, AOCs (natural or human) within or adjacent to the burn site that may be affected by the prescribed burn
- boundaries: good boundaries (low, wet areas, creeks, river, lakes, roads) reduce the complexity and cost of a burn
- surrounding area: neighbouring stands must be examined and described
- history of the site: check for past and proposed management activities
- water sources: a good water source for suppression
- smoke: evaluate the smoke management hazard by considering proximity to human habitation
- overstory: if residual trees were left on site, their value should be assessed, a decision should be made whether they need to be protected or not, and if so, they should be inventoried
- ground vegetation: distribution, species and size of ground vegetation should be recorded.
- topography and slope: used to assess difficulty of burning, ignition strategy, fire behaviour, value protection
- size of area: affects resources needed for the burn and the burn cost

- soils: once the forest manager has assigned an ecosite classification to the site, the range of soil parameters that are common within that ecosite will be known. Important parameters to note are moisture regime and texture that indicate potential for re-vegetation.

DETAILED FUEL DESCRIPTION

Fire behaviour on a burn is determined in part by availability and types of fuel within the burn boundary. Give a detailed description of fuel complexes on site. Depth, arrangement and continuity for fuel complexes should be characterized using *Measurement and Description of Fuels and Fire Behaviour on Prescribed Burns: A Handbook* (McRae *et al.* 1979). The fuel complex should be defined in terms of:

- forest floor cover (needle litter, grass, hardwood leaf litter, moss cover)
- organic layer (duff)
- surface fuels (herbaceous cover, down woody material).

Fuel loading plots should be established. Pre-burn sampling quantifies the initial loading and depth of fuels, which aids in prescription setting. Sampling methods presented in McRae *et al.* (1979) are commonly used in Ontario.

SETTING OBJECTIVES

Objectives for prescribed burns usually include targets for slash fuel loading and duff reduction. An example of objectives used in previous burns are:

- reduction of fine fuels (0 to 7 cm) 40 to 80 per cent
- reduction of heavy fuels (>7.0 cm) 10 to 50 per cent
- reduction of duff layer by 2 to 6 cm.

Even the hottest fire will not remove 100 per cent of the fine fuels from the entire site. To reduce cost and for effective fire management, 40 to 80 per cent fine fuel reduction is a realistic target. It is usually difficult to remove more than 1/3 of the heavy fuels. Therefore, a 10 to 30 per cent reduction target is realistic. However, when heavy fuels are well cured and fire is of high intensity, 30 to 50 per cent of the heavy fuels can be consumed. Mineral soil exposure only occurs on well-drained sites or areas of shallow duff, normally found on ridge tops or on southwest facing slopes. For site protection purposes, mineral soil exposure should not be a target and should be kept below 10 per cent.

TIMING THE BURN

If duff reduction is not a requirement, then the burn can be done in the spring. In the spring, duff will not burn on the lower, north- and east-facing slopes because they are still damp or frosted. Depth of duff will be reduced on the remaining area, but mainly only surface fuels and small fine fuels are consumed.

When duff reductions are an objective, the burn is usually done in the summer when deeper layers of duff have dried out sufficiently to burn.

SETTING THE PRESCRIPTION

A typical prescription for a summer slash burn that has mainly slash fuels (S-1) would be as follows:

- FFMC 83 to 91
- BUI 25 to 40
- ISI <8

When FFMC is below 85, the helitorch is preferred over the OAID for aerial ignition.

- as BUI increases, so does smouldering and time required for post-fire suppression.
- for aerial ignition and a convection burn, wind speed should be <15 km/hr. Upper wind speed limit is set to aid the creation of a convection column which will reduce spotting outside the burn area. Wind direction should be set and will depend on smoke management and fire suppression objectives.
- on shallow sites, a DMC below 20 is recommended to avoid excessive duff removal and bedrock exposure.
- season and prescription (range of indices) can be imputed into the PBWX computer program (Martell 1978) to calculate probability of that prescription occurring and the expected number of days that the prescription will occur for the prescribed burn site.
- assistance in developing a prescription can be obtained from various sources including Stocks and Walker (1972), McRae (1980, 1985), OMNR (1996).

FIRE BEHAVIOUR PREDICTION

Fire behaviour can be predicted for both low and high ends of the prescription range using the "Canadian Forest Fire Danger Rating System" (CFFDRS). Predictions can be made for each fuel type present on the site. Fire behaviour variables that can be analyzed include: rate of spread (m/minute), fuel consumption (kg/m^2), and frontal fire intensity (kW/m), and potential for spotting. Rates of spread can be adjusted using the Canadian Forest Fire Behaviour Prediction System.

ASSESSING BURN EFFECTS

It is important to assess whether the treatment met objectives for two reasons: 1) to determine if results were as expected, and 2) to document results as a learning experience which will assist in planning future treatments.

There are some critical factors that need to be measured to assess the success of a post-harvest burn:

- fuel: pre-burn and post-burn depth of duff and slash loading using the line-intercept method

- rates of spread

- fire intensity calculation

- pre-burn and post-burn effect on shrubs and residual trees, including:

    - number/m^2
    - height
    - per cent cover.

- herb layer assessment, including:

    - pre-burn and post-burn number of species present
    - frequency.

Methodologies are not currently available to monitor the effects of a post-harvest burn on vegetation. However, duff and slash reduction are estimated using fuel loading plots that are established before the burn.

Site vegetation should be monitored if one of the burn objectives is to control competing vegetation. An example of the plot that could be established for long-term monitoring is described in the *Fire Monitoring Handbook* (USDI 1992) produced by the United States National Park System.

7.3.3.7 Ecosite specific considerations

It is important to remember that the following information applies to average conditions found within ecosites. Individual stands may have characteristics that deviate from the average. A careful and thorough site inspection should be done on all stands that are being considered for understory burning.

Interpretations for northwestern or northeastern Ontario ecosites or site types can be made by examining the ecosite equivalency table (TABLE 3.0.3) in Section 3.0 “Characteristics of the Great Lakes-St. Lawrence Conifer Forest” and using information presented in this guide on autecology of both crop and non-crop vegetation (***see*** Section 3.5.7 “Autecology of Associated Species”) and use of prescribed fire (described earlier in this section).

Understory burning

Central Ontario ES 11.1, 11.2, 12.1, 12.2, 13.1, 13.2

These ecosites are potentially good candidates for understory burning. Given ideal conditions, they should successfully regenerate to white or red pine. Characteristics that make them good candidates for pre-harvest prescribed fire are:

- High percentage of conifer litter (50 per cent or more). Conifer litter (C5) provides uniform fire spread before understory green-up.

- “x.1” sites should dry out more quickly in spring and leaf litter fuels will likely show better fire spread earlier in spring than “x.2” types.

- High percentage of pine in overstory - should provide an ample amount of seed during a good seed year.

- Shallow organic mat (over 80 per cent of sites have less than 10 cm of organic matter). Burning off the top litter layer of the forest floor should provide a good seedbed for red and white pine.

- Low levels of hardwood trees and shrubs in the regeneration layer and sub-canopy. One fire should reduce the per cent cover of these competitors and although they will produce sprouts after the fire, there will still be a large area for white and red pine to regenerate.

CONSIDERATIONS

- Balsam fir and spruce in the regeneration layer (5 to 15 per cent cover) and sub-canopy (12.1 has up to 10 per cent balsam fir and 13.2 has up to 20 per cent white spruce) can provide ladder fuels causing fire to spread upwards to damage the overstory. Check their distribution and position relative to each other and to overstory pine.

- Wild lily-of-the-valley, bracken fern, and large-leaved aster are fairly abundant on all these ecosites. Depending on their abundance on the targeted site, the fire may need to be ignited before green-up or they will impede fire spread at the low end of the indices. Wild lily-of-the-valley and large-leaved aster will green-up before bracken fern. The end of the burning window occurs when bracken fern fronds are fully expanded.

- Over 50 per cent of pole sized snags are conifer. They may increase fire intensity and thus increase probability of damage to overstory trees.

- Approximately 25 per cent of these ecosites have shallow soils and shallow organic mats. Feeder roots of overstory trees are close to the surface and burning should not occur in summer; it should only be done in spring when duff is moist and there is no chance of smouldering. Be especially cautious on ES 13.1 where 55 per cent of sites have <30 cm of soil and 90 per cent have <10 cm of organic matter.

- Be aware of slopes on these ecosites. Over 65 per cent of sites are on slopes, with over 35 per cent being on upper slope positions. Slope has a strong influence on fire behaviour and intensity.

Expected results:

- Leaf and litter reduction, but no reduction of the humus layer.

- Good control of balsam fir and spruce (90 to 100 per cent).

- Good top-kill of small diameter hardwood regeneration (<2.5 cm DBH) and shrubs. These will re-sprout after fire but their height and per cent cover should be reduced from pre-burn conditions for 2 to 3 years, as long as harvesting operations do not commence.

- Good white and red pine regeneration if burning coincides with a good seed year.

- Advanced white and red pine regeneration will be killed.

- Little damage to overstory pine trees, if the fire is ignited within the range of indices and if ignition strategies that minimize fire intensities in areas with increased fuel or steep slopes are used. Balsam fir and spruce will likely torch but should not cause significant damage to overstory.

- Red oak, bracken fern, large-leaved aster, and blueberries will respond favourably to fire.

Central Ontario ES 14.1, 14.2

These ecosites are less suitable for understory burning than ecosites 11, 12, and 13 because they have a higher levels of understory hardwood trees and shrubs. However, depending on site and management objectives for these sites, an understory burn can be conducted and achieve some of the objectives. Some characteristics that make these sites good candidates for understory burns are:

- Fair proportion of conifer litter (25 to 30 per cent). Conifer litter (C5) provides uniform fire spread before understory green-up.

- "x.1" sites should dry out more quickly in spring and leaf litter fuels will likely show better fire spread earlier in spring than "x.2" types.

- Shallow organic mat (over 85 per cent of sites have less than 10 cm of organic matter). Burning off the top litter layer of the forest floor should provide a good seedbed for red and white pine.

- These ecosites have a low balsam fir and spruce component in the regeneration and sub-canopy layers. Overstory damage from potential ladder fuels is minimal.

CONSIDERATIONS

- Because of higher hardwood component in the overstory, they have a higher proportion of broadleaf litter (D1). Fire spread will be more erratic and the burn will be more patchy.

- Wild lily-of-the-valley, bracken fern, and large-leaved aster are fairly abundant on both of these ecosites. Depending on their abundance on targeted sites, the fire may need to be ignited before green-up or fire spread will be impeded at the low end of the indices. Wild lily-of-the-valley and large-leaved aster will green-up before bracken fern. The end of the burning window occurs when bracken fern fronds are fully expanded.

- These ecosites have over 40 per cent cover understory hardwood trees and shrubs. They will produce vigorous sprouts after a fire and a second burn or follow-up herbicide treatment will likely be required.

- Be aware of slopes on these ecosites. Over 80 per cent of sites are on slopes, with over 50 per cent being on the upper slope position. Slope has a strong influence on fire behaviour and intensity.

Expected results:

- Patchy leaf and litter reduction, no reduction of the humus layer.

- Good control of balsam fir and spruce (90 to 100 per cent).

- Good top-kill of small diameter hardwood regeneration (<2.5 cm DBH) and shrubs. These will re-sprout after fire but their height and per cent cover should be reduced from pre-burn conditions for 2 to 3 years, as long as harvesting operations do not commence. Because of the high per cent cover of hardwoods on these ecosites, a second burn or a follow-up chemical treatment will likely be required.

- Patchy white pine and possibly red pine and hemlock (14.1) regeneration if the burn coincides with a good seed year. Supplemental planting may be necessary because of high levels of hardwood competition on these sites.

- Advanced white pine regeneration will be killed.

- Little damage to overstory pine trees, if fire ignited with the range of indices and if ignition strategies that minimize fire intensities in areas with increased fuel or steep slopes.

- Red oak, bracken fern, large-leaved aster, and blueberries will respond favourably to fire.

Central Ontario ES 16.1

This ecosite could be considered for a pre-harvest prescribed burn to promote white pine regeneration. Red pine and cedar regeneration may also be promoted. However, understory conifer distribution and size must be carefully examined. Depending on local site conditions, the cover of understory conifers (average 30 to 40 per cent) may be too continuous and the site may not dry out enough to permit fire spread. If burning conditions are met, these understory conifers can create ladder fuels and overstory trees may be damaged.

Central Ontario ES 20.1, 20.2

These ecosites are less suitable for understory burning than ES 11, 12, and 13 because they have a larger hardwood component in the overstory and understory. However, depending on site conditions and management objectives, an understory burn can be conducted and achieve the objectives. Characteristics that make these sites good candidates for understory burns are:

- They have a high percentage of conifer litter (60 per cent or more). Conifer litter (C5) provides uniform fire spread before understory green-up.

- "x.1" sites should dry out more quickly in spring and the leaf litter fuels will likely show better fire spread earlier in spring than "x.2" types.

- High percentage of pine and spruce in overstory - should provide an ample amount of seed during a good seed year.

- Shallow organic mat (over 65 per cent of sites have less than 10 cm of organic matter). By burning off the top litter layer of the forest floor, it should provide a good seedbed for red and white pine and white spruce.

CONSIDERATIONS

- These ecosites have a high balsam fir and spruce component in the regeneration layer (25 per cent cover in 20.1 and 20 per cent cover in 20.2 and a presence of spruce in the sub-canopy. Balsam fir and spruce can provide ladder fuels causing fire to spread upwards to damage the overstory. Check their distribution and position relative to each other and to overstory crop trees.

- Wild lily-of-the-valley, bracken fern, and large-leaved aster are fairly abundant on both of these ecosites, especially on 20.2. Depending on their abundance on the targeted site, fire may need to be ignited before they green-up or they will impede fire spread at the low end of the indices. Wild lily-of-the-valley and large-leaved aster will green-up before bracken fern. The end of the burning window occurs when bracken fern fronds are fully expanded.

- These ecosites have over 40 per cent cover of hardwood trees and shrubs in the regeneration layer. They also have trembling aspen and white birch in the overstory. These species will produce vigorous sprouts, root suckers, and will seed-in after a fire and a second burn or follow-up herbicide treatment will likely be required.

- Over 50 per cent of pole-sized snags are conifers. They may increase fire intensity and increase the probability of damaging overstory trees.

- Be aware of slopes on these ecosites. Over 70 per cent of sites are on slopes, with over 30 per cent being on the upper slope position. Slope has a strong influence on fire behaviour and intensity.

Expected results:

- Leaf and litter reduction, but no reduction of the humus layer.

- Good control of balsam fir (90 to 100 per cent).

- Good top-kill of small diameter hardwood regeneration (<2.5 cm DBH) and shrubs. These will re-sprout after fire but their height and per cent cover should be reduced from pre-burn conditions for 2 to 3 years, as long as harvesting operations do not commence. Because of high per cent cover of hardwoods on these ecosites, a second burn or a follow-up chemical or manual treatment will likely be required.

- Good white pine, red pine and white spruce regeneration if the burn coincides with a good seed year. However, supplemental planting may be required because of high levels of hardwood competition on these sites.

- Advanced white pine and white spruce regeneration will be killed.

- Little damage to overstory crop trees, if fire is ignited within the range of indices and if ignition strategies that minimize fire intensities in areas with increased fuel or steep slopes are used.

- Red oak, bracken fern, large-leaved aster, and blueberries will respond favourably to fire.

- Trembling aspen will likely root sucker and white birch will seed-in after fire.

Central Ontario ES 21.1, 21.2

ES 21.1 could be considered for understory prescribed fire to promote white pine, cedar, and white spruce regeneration. ES 21.2 is likely too moist and fire will not spread unless drought conditions are present or fire will be restricted to upland portions. On ES 21.1, success of the burn will depend on local site characteristics including cover of understory hardwoods and tall shrubs. Balsam fir (average 15 to 20 per cent cover) will be killed by fire. Hardwoods (red maple, white birch 10 per cent cover) will be top killed but will re-sprout, with red maple re-sprouting more vigorously than white birch. Tall shrubs (mountain maple, beaked hazel 20 to 25 per cent cover) will also be top-killed and will re-sprout after fire. White birch will likely seed-in after fire. Advanced cedar regeneration will be killed by fire, and sub-canopy conifers will likely be damaged (cedar, white spruce). Areas with needle litter will burn more readily than areas with broadleaf litter, therefore, the burn and the resulting seedbed will be patchy rather than continuous. Burning should be planned before a good seed year. Chemical site preparation or a tending treatment will likely be required on this ecosite to control competing vegetation.

Central Ontario ES 30.1, 30.2

These ecosites could be considered for understory prescribed fire to promote hemlock, white pine (depending on overstory composition), and possibly yellow birch regeneration. However, success of the burn will depend on local site characteristics including cover of understory hardwoods and tall shrubs, and moisture regime. The burning window will be wider and burning objectives will be met more readily on ES 30.1 as opposed to ES 30.2. Balsam fir (average 10 per cent cover) will be killed by fire. Hardwoods (red maple, yellow birch 10 to 15 per cent cover) will be top-killed but will re-sprout, with red maple re-sprouting more vigorously than yellow birch. Tall shrubs (striped maple, mountain maple, beaked hazel 15 to 20 per cent cover) will also be top-killed and will re-sprout after fire. Areas with needle litter will burn more readily than areas with broadleaf litter, therefore, the burn and resulting seedbed will be patchy rather than continuous. Burning should be planned before a good seed year. Chemical site preparation or a tending treatment may be required on this ecosite to control competing vegetation.

Post-harvest broadcast burning

Central Ontario ES 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 30.1

Broadcast burning can be used on sites that are targeted for spruce or pine restoration. Note that standards or seed trees that are left behind on these sites will likely be killed by fire.

- Fuel Type S2 - Slash - Fairly continuous needle litter on 30.1, mainly broadleaf litter on the other ecosites, moderately thin compact organic layer.

- Continuous slash, moderate foliage retention, moderate loading and fuel depth, moderate to high shrub and herb cover.

- Slash is from clearcutting of mature or over-mature conifer and hardwood and balsam fir understory.

CONSIDERATIONS

- High levels of deciduous vegetation may require a pre-burn herbicide treatment if burn is delayed for more than 1 growing season after harvesting.

Expected results:

- Aspen suckering could be very vigourous

- Sprouting of deciduous species will occur within 1 year

- Quick re-growth of bracken fern, large-leaved aster and blueberry. Because these sites are highly competitive, vegetation should be monitored in case a follow-up tending treatment is needed.

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7.4 Renewal

7.4 Renewal

by Fred N.L. Pinto

Renewal involves a planned set of interrelated treatments (treatment regimes) usually including some of the following:

- site preparation using fire, mechanical or chemical means, in combination or alone
- natural regeneration through seeding and/or use of advanced regeneration
- assisted seeding
- planting.

These treatments may be used to meet management objectives and site-specific targets. They create conditions that favour establishment and growth of desired tree species in amounts and sizes desired.

Unplanned or poorly planned renewal operations may occasionally result in a desired forest condition, but more often they do not. Both Hearnden *et al.* (1992) and OMNR (1995) describe the results of no regeneration planning and poor planning. For example, in a special survey most planted white spruce sites in the Great Lakes-St. Lawrence forest were found to be dominated by poplar, red maple and balsam fir (OMNR 1995).

Proper planning and execution of the plan is key to successful forest renewal. The following sections provide descriptions of treatments that may be used to create successful regeneration regimes. These treatments may be used alone or in combination, for example, areas may be allowed to regenerate naturally and also be planted at a low density.

7.4.1 Natural regeneration

Natural regeneration is renewal of desired tree species by self-sown seed or by vegetative means through suckering, sprouting, or layering (OMNR 1996). Great Lakes-St. Lawrence conifers regenerate naturally from seed. Northern white cedar may also regenerate naturally by layering. Renewal of Great Lakes-St. Lawrence conifers may be assisted by protecting regeneration that has established prior to operations.

In the past, natural regeneration has often been poorly planned or unplanned. This resulted in conversion of sites to hardwoods and poor quality conifers. Natural regeneration can be successful if properly planned and executed.

7.4.1.1 Factors to consider for successful natural regeneration

ADAPTATIONS FOR ESTABLISHMENT AND GROWTH

Section 3.4 “Silvics of the Great Lakes-St. Lawrence Conifers” and 3.4.7 “Autecology of Associated Species” describe the adaptations of crop and non-crop species important for renewal. For example, the periodicity of bumper seed-crops of Great Lakes-St. Lawrence conifers is lower than that of many associated tree and shrub species such as balsam fir, white birch, aspen, hazel or mountain maple. As a result, in areas not site-prepared during bumper seed years, regeneration of higher numbers of associated species than of Great Lakes-St. Lawrence conifers may occur.

SITE CONDITIONS

Natural regeneration is likely to be successful when the abundance of non-crop species is low and sufficient water, light and nutrients are available for establishment and growth of crop tree seedlings. These conditions are most common on shallow soils, soils with lower levels of nutrients and moisture retention, that support poorly stocked overstories.

Field experience has shown that the presence of regeneration prior to operations can serve as a good indicator of the likely success one may have in naturally regenerating a site. Per cent cover of already present regeneration of Great Lakes-St. Lawrence conifers and selected competitors in FEC plots are shown in TABLE 7.4.1.

TABLE 7.4.1 may be used to assist in developing silvicultural ground rules. Ecosites with high levels of advance regeneration would in most cases be suitable for natural regeneration. TABLE 7.4.1 may also be used to determine the probable levels of competition that crop tree seedlings will encounter by considering per cent cover of shrub and non-crop advance regeneration. For example, Central Ontario ES 30.1 and ES 30.2 have moderate levels of hemlock advance regeneration, but also have moderate levels of balsam fir and low levels of beaked hazel, mountain maple and red maple. This suggests that appropriate vegetation management treatments must also be included in the treatment package.

TABLE 7.4.1 must not be used to prescribe treatments. Factors that affect natural regeneration are quite variable. A field inspection is usually required to confirm conditions predicted by FEC data are in fact present.

STAND CONDITIONS

Section 3.4 “Silvics of the Great Lakes-St. Lawrence Conifers” provides details on stand conditions that can increase the probability of obtaining desired tree species composition.

TABLE 7.4.1: Average per cent cover of advance regeneration found in FEC plots in each ecosite that may be managed for Great Lakes-St. Lawrence conifers. Ecosites where advance regeneration was not present are not listed in this table.

SPECIES	PER CENT COVER[1]	CENTRAL ONTARIO ECOSITES	NORTHEAST ONTARIO ECOSITES	NORTHWEST ONTARIO VEGETATION TYPES
white pine	High			
	Medium			
	Low	12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 15.1, 16.1, 16.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.1, 25.2, 27.1, 27.2, 28.2, 30.1, 30.2, 31, 32, 33	2b, 3b	37
red pine	High			
	Medium			
	Low	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 16.1		
white spruce	High			
	Medium			
	Low	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 16.1, 16.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.1, 27.1, 27.2, 28.1, 28.2, 29.1, 29.2, 30.1, 30.2, 32, 33, 34, 35	3b, 6a, 6b, 6c	
eastern white cedar	High			
	Medium	22		
	Low	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 15.1, 15.2, 16.1, 16.2, 17.1, 17.2, 18.2, 19.1, 19.2, 20.1, 21.1, 21.2, 23.1, 23.2, 24.1, 24.2, 26.1, 28.1, 28.2, 29.1, 29.2, 30.1, 30.2, 31, 32, 33, 34, 35	3a, 3b, 6a, 6b, 6c, 13	17
hemlock	High			
	Medium	30.1, 30.2		
	Low	11.2, 13.2, 14.1, 14.2, 17.2, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.1, 25.2, 26.2, 27.1, 27.2, 28.1, 28.2, 29.2, 32, 33, 34, 35		

[1] High per cent cover of advance regeneration is greater than 26 per cent
Medium per cent cover of advance regeneration is between 6 per cent to 25 per cent
Low per cent cover of advance regeneration is lower than 6 per cent but greater than 0 per cent

TABLE 7.4.1: Average per cent cover of advance regeneration found in FEC plots in each ecosite that may be managed for Great Lakes-St. Lawrence conifers. Ecosites where advance regeneration was not present are not listed in this table.				
SPECIES	PER CENT COVER[1]	CENTRAL ONTARIO ECOSITES	NORTHEAST ONTARIO ECOSITES	NORTHWEST ONTARIO VEGETATION TYPES
balsam fir	High			
	Medium	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 15.1, 16.1, 16.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.2, 24.1, 26.2, 27.1, 27.2, 29.2, 30.1, 30.2, 32, 33, 34	6a, 6b, 6c	11, 15, 17
	Low	15.2, 23.1, 24.2, 25.1, 25.2, 26.1, 28.1, 28.2, 29.1, 31, 35		18, 24, 37
white birch	High			
	Medium			17
	Low	11.1,11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 15.1, 15.2, 16.1, 16.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.1, 25.2, 27.1, 27.2, 29.1, 29.2, 30.1, 30.2, 31, 32, 33, 34, 35	2a, 2b, 3b, 6a, 6b, 6c, 13	11, 15, 18, 24, 37
red maple	High			
	Medium	11.1, 11.2, 12.2, 13.1, 13.2, 14.1, 14.2, 17.1, 20.2, 23.1, 27.1		
	Low	12.1, 15.1, 15.2, 16.1, 16.2, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 21.1, 21.2, 22, 23.2, 24.1, 24.2, 25.1, 25.2, 26.1, 27.2, 28.1, 28.2, 29.1, 29.2, 30.1, 30.2, 31,, 32, 33, 34, 35	3b, 6b, 6c,	11, 15, 17, 24,
trembling aspen	High			
	Medium			
	Low	11.1, 11.2, 12.1, 12.1, 13.1, 13.2, 14.1, 14.2, 15.2, 16.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.1, 25.2, 26.1, 26.2, 27.1, 27.2, 29.2, 33, 34, 35	2a, 2b, 3b, 6a, 6b, 6c	11,15, 17, 18, 24

[1] High per cent cover of advance regeneration is greater than 26 per cent
Medium per cent cover of advance regeneration is between 6 per cent to 25 per cent
Low per cent cover of advance regeneration is lower than 6 per cent but greater than 0 per cent

TABLE 7.4.1: Average per cent cover of advance regeneration found in FEC plots in ecosites with selected non-crop species

SPECIES	PER CENT COVER[1]	CENTRAL ONTARIO ECOSITES	NORTHEAST ONTARIO ECOSITES	NORTHWEST ONTARIO VEGETATION TYPES
mountain maple	High			
	Medium	17.1, 17.2, 18.1, 18.2, 20.1, 20.2, 21.1, 21.2, 22, 27.1, 29.1, 29.2, 34, 35	6c	15, 24,
	Low	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 15.1, 15.2, 16.1, 16.2, 19.1, 19.2, 23.1, 23.2, 24.1, 24.2, 25.1, 25.2, 26.1, 26.2, 27.2, 28.1, 28.2, 30.1, 30.2, 32, 33, 34, 35	3b, 6a, 6b	11, 17, 18
speckled alder	High			
	Medium	32	13	
	Low	11.1, 11.2, 15.2, 16.1, 16.2, 17.2, 18.1, 18.2, 19.2, 20.2, 22, 27.1, 27.2, 30.2, 31, 33, 34, 35	3a, 3b, 6a, 6b, 6c	11, 15, 17, 18, 24, 37
beaked hazel	High			
	Medium	11.2, 12.1, 12.2, 13.2, 14.2, 17.1, 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 23.2, 24.2, 27.1, 27.2, 29.2,	6c	15, 17, 24
	Low	11.1, 13.1, 14.1, 15.1, 15.2, 16.1, 16.2, 22, 23.1, 24.1, 25.1, 25.2, 26.1, 26.2, 28.1, 28.2, 29.1, 30.1, 30.2, 31, 32, 33, 34	2b, 3a, 3b, 6a, 6b, 13	11, 37
bracken fern	High			
	Medium	11.1, 11.2, 12.1, 12.2, 13.1, 13.2, 14.1, 14.2, 17.2, 18.2		
	Low	15.1, 15.2, 16.1, 16.2, 17.1, 18.1, 19.1, 19.2, 20.1, 20.2, 21.1, 21.2, 22, 23.1, 23.2, 24.1, 24.2, 25.2, 27.1, 27.2, 28.2, 29.1, 29.2, 31, 32, 33, 34, 35	2a, 2b, 3a, 3b, 6a, 6b, 6c	15, 17, 18, 24

[1] High per cent cover of advance regeneration is greater than 26 per cent
Medium per cent cover of advance regeneration is between 6 per cent to 25 per cent
Low per cent cover of advance regeneration is lower than 6 per cent but greater than 0 per cent

7.4.2 Planting

Planting is used to regenerate areas where:

- crop tree seed sources are missing, such as in clearcuts or abandoned fields
- seedling establishment is considered to have a low probability of occurring, e.g. white pine or red pine may be planted in shelterwood cut sites if seed crops do not coincide with site preparation
- competition from non-crop plants limits survival of naturally regenerated seedlings
- conditions or events limit the manager's ability to create site conditions that favour germination of seeds of desired trees.

Even though planting has a long history in Ontario, success is not always assured. For example, surveys show white pine, red pine and white spruce plantations were in most cases over-topped by poplar, red maple or balsam fir (OMNR 1995).

Failure of most of these plantations can be attributed to:

- failure to develop and implement adequate pre- and post-treatments
- poor stock quality
- poor planting stock storage and handling practices
- failure to consider all known factors, such as browsing, that may impact on planting success.

Planting programs are more successful when:

- proper attention is paid to planting stock and site selection
- planting stock is properly stored and handled (***see*** *Guidelines for Proper Handling of Planting Stock* available from OMNR Science Specialists)
- stand and site conditions before and after harvest are carefully considered and a vegetation management strategy is developed
- the consequences of all known factors are considered. For example, are ungulate populations likely to be high when the seedlings are within browsing height? Many cedar and hemlock plantings have failed in central Ontario because they were established within areas prone to high browsing pressure from deer or moose.

7.4.2.1 Stock selection and timing of planting operations

Many different nursery stock types are available today. Johnson *et al.* (1996) describes stock types currently in use in Ontario. Most forest managers know that it is important to match stock (species, stock size and method of culture) to site conditions.

Information on planting stock performance of conifers in the Great Lakes-St. Lawrence forest is limited. Results on planting white spruce in boreal sites suggest that larger stock is usually better than smaller stock (McMinn 1982, 1985). Studies comparing container stock with bare-root stock suggest that if both stock types are similar in size at the time of planting, container stock will have better survival and growth size (Mattice 1982; Alm 1983; Scarratt and Wood 1988).

There is evidence, primarily from boreal planting trials, that spring is the best season to out-plant seedlings (Mattice 1982; Marion and Alm 1986; Scarratt and Wood 1988).These findings support operational experience that spring planting in the Great Lakes-St. Lawrence forest results in good performance. However, there have been very few operational fall plantings in the Great Lakes-St. Lawrence forest in recent years to determine the comparative advantages of late season planting on seedling performance.

7.4.2.2 Stand and site conditions

Harvest operations often result in removal of merchantable tree stems. Unmerchantable stems, left behind in either partial cuts or clearcuts, can quickly occupy clearings by growing larger or by producing progeny. These conditions are an important factor that contribute to the failure of many plantations. For example, mixedwood sites with low quality white birch, red maple, balsam fir along with pine and spruce are often converted to pulp quality species when only the pines and spruces are harvested. Follow-up site preparation and tending is required when tree-size, polewood-size or seedling-sized stems of potentially competing species are left in cutovers.

Ecosites may be used to match desired tree species and site conditions. Ecosite groupings (***see*** Section 7.2 "Silvicultural Systems") may be used to identify suitable species and site matches when developing Silvicultural Ground Rules.

7.4.2.3 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 vigour 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 such as attainment of forest structure allowable cut 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 brochures on stock handling and storage. To minimize planting unhealthy seedlings, it is recommended that seedlings are inspected before shipping and monitored regularly in the field by trained people. Seedling quality may be more accurately determined through standardized tests that determine the seedling's 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 and Sampson 1997). Resource managers may obtain tests to certify nursery stock lots or to test questionable stock before shipping or planting. Sources of standardized seedling-quality tests are currently limited in Ontario. The location of seedling testing services may be obtained through your local OMNR Science Specialist.

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7.4.3 Determining Seeding Rates

7.4.3 Determining Seeding Rates

by Luc C. Duchesne, Tannis Beardmore and Richard Reader

Predicting regeneration of tree species is critical to achieving forest and site-specific objectives. However, despite the best of intentions, it is often difficult to forecast regeneration in post-disturbance ecosystems because of: 1) a general lack of information about the factors that control seed germination and seedling establishment for the first growing season and 2) the stochasticity of factors that reduce seed abundance and quality such as predation, browsing (Nelson 1951), trampling (Larson 1990), climate and diseases.

In general, seedbed moisture is the most important factor for germination and early survival of conifer seedlings. In northern ecosystems, moisture problems are often caused by the fact that the slowly decomposing organic material overlying the mineral soil limits the availability of moisture (Smith 1951; Arnott 1974; Chrosciewicz 1974; Chrosciewicz 1978; Ahlgren and Ahlgren 1981). Hence, the success of many silvicultural programs depends largely on the reduction of this material either through prescribed burning or mechanical means (Logan 1951; Horton and Bedell 1960; Ahlgren 1976; Balmer and Williston 1983; Thomas and Wein 1985).

Lack of soil water may contribute to poor conifer seedling emergence on unburned seedbeds as well as on burned seedbeds (Arnott 1974; Thomas and Wein 1985). Water retention capacity is lowest at the top of the organic horizon (Mallik *et al.* 1988), where wind dispersed conifer seeds are initially deposited. Experimental evidence suggests that the detrimental effect of low water retention capacities associated with thicker organic horizons on seedling emergence may be negated by either increasing water supply or by adding shade to reduce evaporation (Herr and Duchesne 1995, 1996).

This section contains a practical guide to determine seed needs when planning seeding treatments. This model was originally developed and tested for the restoration of white and red pine in clearcuts in Quebec. Since then the scope of work has been expanded for other tree species. It has been developed through greenhouse tests, described by Herr *et al.* (1995), for northern white cedar, white spruce, red spruce, eastern hemlock and balsam fir. Because of its limited field use, the models should be used with caution and altered as information for local conditions becomes available. The germination models presented can be viewed as a starting point to help forest managers understand some of the factors that affect seeding success and to build a customized guide adapted to local conditions and requirements.

7.4.3.1 Predicting seed germination

TABLE 7.4.2 shows a step-by-step procedure for seeding projects. Forest managers should use this table to determine the germinability of their seedlots (***see*** sections 7.4.3.2 and 7.4.3.3). Next, they should assess the sunlight conditions at the seeding microsites and correct the amount of seeds required to account for the negative impact of too much shade or too much sunlight (***see*** sections 7.4.3.4 and 7.4.3.5). Corrections should also be made to the seeding intensity calculation if seed shelters are used (***see*** section 7.4.3.6). Adjustment is also required to account for the natural attrition rate of seedlings from the germination stage to stand maturity (***see*** Section 7.4.3.7). Seeding requirements are then scaled-up to match the proposed size of the area to be seeded (***see*** Section 7.4.3.8).

TABLE 7.4.2: Step-by-step procedures for seeding projects		
STEP	OBJECTIVES	REFERENCE
1	Determine seed germinability	Section 7.4.3.2
2	Enter seed germinability into seeding equation	Section 7.4.3.3
3	Determine effect of shade on germination	Section 7.4.3.4
4	Modify seeding intensity to accommodate for shade/competition effects	Section 7.4.3.5
5	Modify seeding intensity if seed shelters are used	Section 7.4.3.6
6	Modify seeding intensity to accommodate for natural seedling attrition to stand maturity	Section 7.4.3.7
7	Scale up results to the size of the area to be seeded	Section 7.4.3.8

7.4.3.2 Seed germinability and stratification

The germinability of conifer seedlots varies according to species, site, seed storage conditions, length of storage, seedlot quality, insects, pathogens and stratification. For artificial seeding, because seedlots are provided by central agencies, forest practitioners have little or no control over most of these factors except for stratification. Proper stratification improves germination significantly (Schopmeyer 1974) and dramatically reduces the cost of artificial seeding. Consequently, in view of the cost of seedlots, it is more economical to use stratified seeds rather than unstratified material. For this, forest managers should follow stratification methods which have been developed for conifers (Schopmeyer 1974).

For natural seeding projects, it is critical for the forest manager to forecast the germination rate and abundance of the seed crop. Unfortunately, there is presently no reliable model to accomplish this task. Indeed, probabilistic models on seed crops are not realistic to use, particularly for species such as white pine which can have long intervals between seed years. An easy procedure to forecast seed production based on field assessment of cones is suggested instead. The forecasting of seed crops is most accurate when data is collected shortly before cone maturity.

Procedures are as follows:

1) all cones should be collected from triplicate 10 m x 10 m sub-plots within the target area (cone development should be close to maturity)

2) dry cone production (measured in kg/ha) is then determined by multiplying the averaged values obtained in 1) *above* by 100

3) using the fourth column of TABLE 7.4.3, the value obtained in step 2) is then transformed into *kg seeds/ha*. For example, if the white spruce cone production of a test area is 100 kg/ha then the seed production should be: 100 kg cones/ha x 0.012 kg seeds/kg cones = 1.2 kg seeds/ha

4) this data can be used in TABLE 7.4.2 to forecast germination and seedling establishment. One advantage of predicting seed crops is that managers may elect to supplement natural seeding with artificial seeding or planting if natural cone production is not sufficient.

TABLE 7.4.3: Germination potential, seed density, kg seeds:kg cones ratio for six conifer species (*adapted from*: Schopmeyer 1974)

SPECIES	GERMINATION POTENTIAL (per cent)	SEED DENSITY (seeds/kg)	SEED:CONE RATIO (kg seeds/kg cones)
white spruce	35	497,200	0.012
red spruce	10	305,800	0.023
red pine	20	114,000	0.008
white pine	25	58,300	0.030
eastern white cedar	20	761,000	0.036
eastern hemlock	3	411,400	0.019

7.4.3.3 General germination model

The general model for artificial seeding is presented as ***Formula 1***; the values of the species-specific constants, α and β are listed in TABLE 7.4.4.

$$Seeds\ (kg/ha) = \frac{1}{G} * \frac{1}{S} * \frac{D}{(\alpha+\beta(REM))}$$

where

Seeds : number of kg of seeds to use per hectare

D : number of seedlings per hectare required (determined by forest manager)

S : number of cleaned seeds per kilogram of seed density (determined for each seedlot or use average value provided in TABLE 7.4.3)

G : germination potential of seeds ($0<G<1$) (provided by seed suppliers or for natural seeding, use value provided in TABLE 7.4.3)

REM : per cent humus removal (all layers) after site preparation as compared to undisturbed site (0≤REM≤1) (measured by forest manager and averaged for site to be treated)

α : species-specific constant (*from*: TABLE 7.4.4)

β : species-specific constant (*from*: TABLE 7.4.4)

TABLE 7.4.4: Species-specific constant for the germination of conifer species (Herr *et al.* 1995)

SPECIES	α	β
balsam fir	10.00	19.00
white spruce	8.00	24.10
red spruce	8.06	26.80
red pine	9.00	23.00
white pine	7.01	20.00
eastern white cedar	4.22	13.70
eastern hemlock	2.35	12.20

For example, the number of seeds needed to establish a 1 ha plot of 10,000 seedlings of red spruce with a germination potential of 55 per cent on mineral soil would be:

$$\text{Seeds (kg/ha)} - \frac{1}{0.55} * \frac{1}{305{,}800} * \frac{10{,}000}{8.06 + 26.8(0)}$$

where

Seeds : number of kg of seeds to use per hectare

D : 10,000 seedlings per hectare required

S : 305,800 seeds/kg (*from*: TABLE 7.4.3)

G : germinability of seeds, 0.55 in this example

REM : in this example we use no humus, therefore REM=0

α	:	8.06 (*from*: TABLE 7.4.4)
β	:	26.8 (*from*: TABLE 7.4.4)

7.4.3.4 Effect of shade on seed germination

Recent study results show that conifer germination is reduced by too much light as well as too much shade, with a maximum rate of germination around 50 per cent canopy closure (Herr and Duchesne 1995a, 1995b; Herr 1996). Excessive radiation tends to dry up the seed bed whereas excessive shading reduces photosynthesis of germinating seedlings. Although it is recognized that each conifer species displays a different level of tolerance to these factors, it is not practical to include such differences in this guide. Accordingly, seeding quantities should be corrected to accommodate for excessive shade and sunlight effects. Shading can be assessed using various types of light meters, preferably meters that measure a spectrum covering the entire range of photosynthetically active radiation. In the absence of proper equipment, managers can use canopy closure as an estimate of shading. The shading correction factors is computed as follows:

$$\textit{Shading correction factor} = 1 - \frac{(X-50)^2}{50}$$

where

X is the per cent light available at the seedbed level and is greater than 0 and smaller than 100 because the model does not allow appropriate germination under these conditions. Three examples are shown below:

- under 50 per cent canopy closure, the shading correction factor is:

$$\textit{Shading correction factor} = 1 - \frac{(X-50)^2}{50} = 1$$

- under 99 per cent canopy closure, the shading correction factor is:

$$\textit{Shading correction factor} = 1 - \frac{(X-50)^2}{50} = 0.0396$$

- under 10 per cent canopy closure, the shading correction factor is:

$$\textit{Shading correction factor} = 1 - \frac{(X-50)^2}{50} = 0.36$$

7.4.3.5 Correction of seeding prescription for shading effect

The objective of this step is to modify seeding prescriptions with the seeding correction factor computed in section 7.4.3.4. Thus, seeds requirements obtained from section 7.4.3.3 are modified as follows using the shading correction factor (***see*** section 7.4.3.4).

Seeds (kg/ha) = (section 7.4.3.3)/(section7.4.3.4)

7.4.3.6 Correction for seeding methods

Artificial seeding can be conducted in three general ways: 1) broadcast seeding, 2) even-spaced seeding and 3) microsite seeding. Broadcast seeding can be conducted over large areas using aircraft, mechanical seed dispersers in the field, or even hand delivery of seeds by operators. Broadcast seeding is attractive in ecological restoration because it mimics natural wind-borne seed delivery and it may be low in cost. However, the problem with broadcast seeding is that field conditions vary a great deal and that seeds may fall on unsuitable and suitable microsites.

Evenly-spaced seeding entails the manual delivery of a limited amount of seeds at precise spacing, for example 1 m x 1 m, in a manner analogous to tree planting. The advantage of this method is that the resulting distribution is more acceptable from a silvicultural point of view. However, it requires an even distribution of suitable microsites for seed germination over the treated areas.

For microsite seeding, seed delivery is performed only in suitable microsites to maximize germination. This approach has limited application in forest management unless microsites are evenly distributed. However, a combination of the microsite and even-spacing methods offer the best approach to artificial seeding as it takes advantage of the best microsites which ensure an even seed distribution.

The use of seed shelters, various types of translucent plastic cup-like devices, is recommended to improve microsite conditions and facilitate germination. Small field trials in the Great Lakes-St. Lawrence forest suggest seed shelters may increase seed germination and early establishment in clearcuts. Therefore, forest managers may reduce the amount of seeds required for artificial seeding if shelters are used.

7.4.3.7 Correction for seedling attrition

Mortality of young seedlings and saplings is a common phenomenon in nature. It is caused by herbivory, competition and diseases. Seedling attrition rates to maturity vary a great deal with species and site conditions. Therefore, it is not possible to present species and site specific attrition rates to correct seeding amounts. Rather an overall attrition rate of 90 per cent is suggested. Managers can modify this figure according to their own needs. Hence, seeding requirements are:

Seeds (kg/ha) = (section 7.4.1.6)/0.90

7.4.3.8 Correction for size of area to be treated

Section 7.4.3.7 "Correction for seedling attrition" leads to the computation of final seed requirements, on a per hectare basis. To obtain the total amount of seed required for a project, multiply the kilograms of seed required per hectare by the total number of hectares in the project.

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7.5 Stand Maintenance

7.5 Stand Maintenance

by Scott R. Reid and Murray E. Woods

Forest stand maintenance includes those activities of tending and protection, that are carried out to ensure the survival and development of a forest to maturity (OMNR 1996). For the purposes of this guide, this definition includes tending during the pre-establishment phase. Scheduling of appropriate and timely maintenance activities in conifer stands is essential. The quantity and quality of the trees that constitute stand structure and the time it takes to reach stand objectives depends on the level of maintenance conducted over the rotation.

Pest management must be an integral part of stand maintenance. For example, strategies such as proper site selection and maintenance of key components of the previous stand can help to produce new forest stands that are less susceptible to damage from insects and diseases. Where appropriate, it may be possible to modify maintenance practices to enhance other forest values such as wildlife. For example, high thinning intensities may lead to the development of browse for local deer populations.

7.5.1 Tending

Tending is generally any operation carried out for the benefit of an established forest crop at any stage of its life, for example, cleaning, thinning, stand improvement, and pruning.

All conifers respond well to a number of tending treatments, including cleaning, thinning, and stand improvement. Investments in site preparation are protected through the timely scheduling of mechanical, chemical, or manual cleaning treatments. The harvest method, the amount of competing vegetation, and the effectiveness of site preparation treatments determine the need for cleaning. Thinning and improvement operations increase growth on the residual trees. The quality of crop trees can be significantly enhanced through well-timed pruning. TABLE 7.5.1 summarizes the various types of tending treatments that may be considered (OMNR 1990).

7.5.1.1 Cleaning

Cleaning is an operation carried out in young stands, not past the sapling stage, to free favoured trees from undesirable individuals of similar age or size which overtop them or are likely to do so (OMNR 1996). Cleaning can be accomplished by chemical, mechanical, or manual means. Condition assessments should be conducted to establish the necessity and timing for cleaning treatments. The scheduling of cleaning treatments depends on site conditions, original stand composition, and effectiveness of site preparation. Early release is a critical determinant of plantation survival and growth. A few well-timed release treatments may be necessary to ensure successful establishment, especially on fresh to moderately moist or nutrient-rich sites.

TABLE 7.5.1: Summary of intermediate treatments carried out in stand maintenance				
TREATMENT	STAGE	PURPOSE	WHAT IS REMOVED	TREES RETAINED
EARLY TENDING				
Chemical Cleaning	Seedling / Sapling	Release young trees from competing vegetation.	Grasses, herbs, shrubs, unwanted tree species.	Crop-tree species, regeneration.
Mechanical and Manual Cleaning				Non-crop tree species for shading purposes.
IMPROVEMENT CUTTING				
	10 cm DBH and larger	Improve species composition and quality.	Unwanted species. Poorly formed trees, diseased or insect damaged trees.	Well formed stems. Desirable species with future growth potential.
THINNING				
Low thinning	10 cm DBH and larger	Salvage mortality. Reduce root competition.	Lower crown class.	Middle/upper crown class.
Crown thinning		Increase crop-tree growth. Salvage mortality.	Poorly-spaced trees in upper crown class.	Well-spaced, well-formed trees in upper crown class.
PRUNING				
	10 to 20 cm DBH	Improve lumber quality of selected crop trees.	Lower branches of crop trees, up to 5.1 metres of clear bole.	Minimum 50% live crown must be retained.

Traditional forestry practice has been to cut any competition that might shade the crop trees too heavily or that could cause physical damage by collapsing on them in winter. Before the advent of herbicides, cutting was the only practical way of controlling competition growth after regeneration of crop species. It has been found that cutting non-crop species does little to reduce competition for moisture and nutrients and may even increase it. On dry sites or in dry years cutting competition can reduce the survival of newly planted trees (Hibberd 1991). Competition is most detrimental if the trees have already been stressed; for example by poor handling, storage or planting practices (Hibberd 1991).

On many upland sites where new regeneration becomes established, competing species re-invasion after mechanical site preparation is sufficiently slow to allow satisfactory crop establishment with no further control, but herbicide control will be needed on many unprepared sites. Most lowland sites, even when mechanical site prepared, will require chemical control.

There are six herbicides most commonly used in forestry applications to release crop species (***see*** Section 7.3.2 “Chemical Site Preparation” - TABLE 7.3.4). Herbicides work in a variety of ways, some entering through the leaves of weeds, others through the root system. Herbicides must be applied before crop trees are planted or when crop trees are at a non-vulnerable stage. Otherwise, crop trees must be physically guarded (Hibberd 1991).

The large number of competing and crop species and the variety of herbicides and application methods make the subject a complicated one. For details regarding herbicides registered for use in Ontario, ***see*** TABLE 7.3.4, TABLE 7.3.5, TABLE 7.3.6 and TABLE 7.3.7 in Section 7.3.2 “Chemical Site Preparation”.

Young white pine will benefit from some lateral and high shade, especially on dry sites. Where a nurse crop is used for white pine, competition should be selectively removed while still maintaining the benefit of some cover. A white pine seedling or sapling with a full, healthy crown extending 50 per cent or more of its total height and with a constant leader extension will respond almost immediately to release. The response is much slower where trees possess small, sparse crowns (Lancaster 1984) with diminishing leader extension for the previous two or more years. Shade intolerant red pine (TABLE 7.5.2) is very sensitive to lateral or overhead competition. Over-topping brush and side competition should be eliminated by the fifth year in red pine stands (Struik 1978). Early release treatments are essential for this species.

TABLE 7.5.2: Shade tolerance rating for six species of conifers (Baker 1950)

VERY TOLERANT	TOLERANT	INTERMEDIATE	INTOLERANT
eastern hemlock	red spruce white spruce white cedar	white pine	red pine

Both 2,4-D and glyphosate can be applied in cleaning operations to control competing vegetation. Aerial or ground application may be appropriate, depending on size of the treatment area, access, and block pattern. These treatments should be scheduled after crop trees have set bud and hardened off. Spot applications of hexazinone can be applied at or near bud-break until early summer to release red pine. Application is most effective in the spring after the ground has thawed.

Perennial grasses can be controlled with glyphosate, while simazine is used to control annual grasses and triazine-sensitive weeds. An artificial shield must be used when the trees are in the non-dormant stage to ensure that seedlings are protected from damage by these herbicides.

Mechanical or manual methods of cleaning may be appropriate in some circumstances. Where possible, these treatments should be scheduled when root reserves of competing vegetation are lowest, usually from mid-June to August.

Release treatments may be necessary where there is a hardwood overstory. For white pine, concentrate on removing hardwood species most likely to increase as regenerating competition. At least 50 per cent full sunlight is necessary to ensure appropriate growth response for white pine (***see*** Section 3.5.1 "Silvics - white pine" and Section 3.5.2 "Silvics - red pine"). Complete release from overstory competition is recommended for red pine.

Manual girdling or stem injection methods are effective for liberation of crop trees from a dense overstory. Stem injection method is most effective in late summer or fall. Glyphosate and 2,4-D are registered for this use.

Herbicide application must conform to OMNR Forest Resources Branch Procedure No. FR 04.20. 10 PR (1987) *Aerial Application of Herbicides for Forest Management in Ontario*, and also, to *Aerial Spraying for Forest Management: An Operational Manual* (OMNR 1991). All herbicides must be registered for use in Ontario and label specifications must be strictly adhered to.

The cutting of unwanted woody growth may become necessary in a young plantation or stand after weeding has ceased and trees are properly established. Areas regenerated by direct sowing or natural regeneration usually need to be cleaned to reduce stocking and at the same time remove unwanted species. A judgement always has to be made on the effectiveness of the operation taking into account likely crop losses and the high cost of cleaning (Hibberd 1991).

7.5.1.2 Pruning

Pure stands of either white pine or red pine exhibit relatively poor natural pruning. In contrast, natural pruning is often good where white pine grows in mixedwood stands (Smith and Seymour 1985). In pure, dense stands, lower branches die and are retained for years, especially on white pine. These provide entry points for decay fungi and result in the incorporation of loose knots in the wood (Horton and Bedell 1960), which adversely affects log grade potential. Crop trees should be pruned soon after thinning or improvement operations have been completed. Conditions favouring rapid growth are optimal at this time, and branch stubs heal over quickly (Lancaster 1984; Smith and Seymour 1985).

Priority should be given to stands growing on the best sites. Here, pruning costs tend to be lower because of greater internodal lengths and small branch diameters. Where low-density management strategies are used, the potential for the formation of dead branches and associated loose knots is lower. However, pruning costs may be higher because of larger branch diameters. Pruning of white pine has been justified in many cost/benefit studies (Lancaster 1984; Robbins 1985) if the trees or logs are sold using a bid system.

Pruning, properly done, is one of the best ways to assure high quality wood. The primary questions are which species should be pruned and what is proper pruning? Local markets and the stand stocking level will determine whether you should undertake pruning. Once the decision has been made to prune, it is important to carry out the operation properly. A proper cut removes the living, dying, or dead branch by cutting as close as possible to the collar at the branch base. The collar should not be injured or removed. The collar may be naturally swollen, and the swollen collar that remains is not considered a stub. On dead branches, a ring of living tissue surrounds the branch at its base. Do not injure or remove the ring of living wood. Avoid making flush pruning cuts. This can cause a multitude of serious problems, including discoloured wood, decayed wood, wet wood, resin-soaked wood, a host of cankers, cracks, dead spots, and insect sites.

Once the decision has been made to undertake a pruning project it must be decided which trees to prune, how many to prune, how much to prune from each tree and the recording and maintenance of identified pruned crop trees. If the growth and quality of the pruned crop trees is not improved or identifiable in the future, there is no financial benefit of the pruning. They must be identified to distinguish them from neighbouring naturally pruned trees, since the clear lumber will be greater in the pruned trees and is of higher value. They also must bear identification to prevent their removal in thinning operations that may occur before the pruning benefits have had time to at least break even with the costs. Economically, it only makes sense to prune if there is a higher stumpage charge for the pruned trees. This requires good records and the ability to tender the sale of the standing timber to the highest bidder. If this is not possible, or records are not good, then it would not be wise to invest in pruning.

7.5.1.3 Thinning

Thinning is a significant mechanism for controlling stand growth and shaping future stand structure. It is undertaken to increase diameter growth of crop trees in the residual stand, maintain stand health, salvage trees at risk of mortality, achieve desired quality and species composition and to improve stand quality (Ernst and Knapp 1985; OMNR 1986b). Ground vegetation (e.g. herbs and shrubs) may develop at higher levels of thinning intensity, which may be of value to some wildlife species. Also, thinning facilitates access into stands for recreational activities and may reduce the visual impact of rows of trees in plantations.

Current thinning practices attempt to change stand structure to meet management objectives. For example, if large diameter trees are required within a defined time frame, then proper thinning will redistribute the potential stand growth to fewer, but larger (usually higher quality) trees.

When developing thinning options and prescriptions, resource managers require information on management objectives and current stand density, in order to determine the desired residual stocking levels for optimal stand growth. Density management diagrams provide a means to visually illustrate current stand condition and plan and track future stand trajectories.

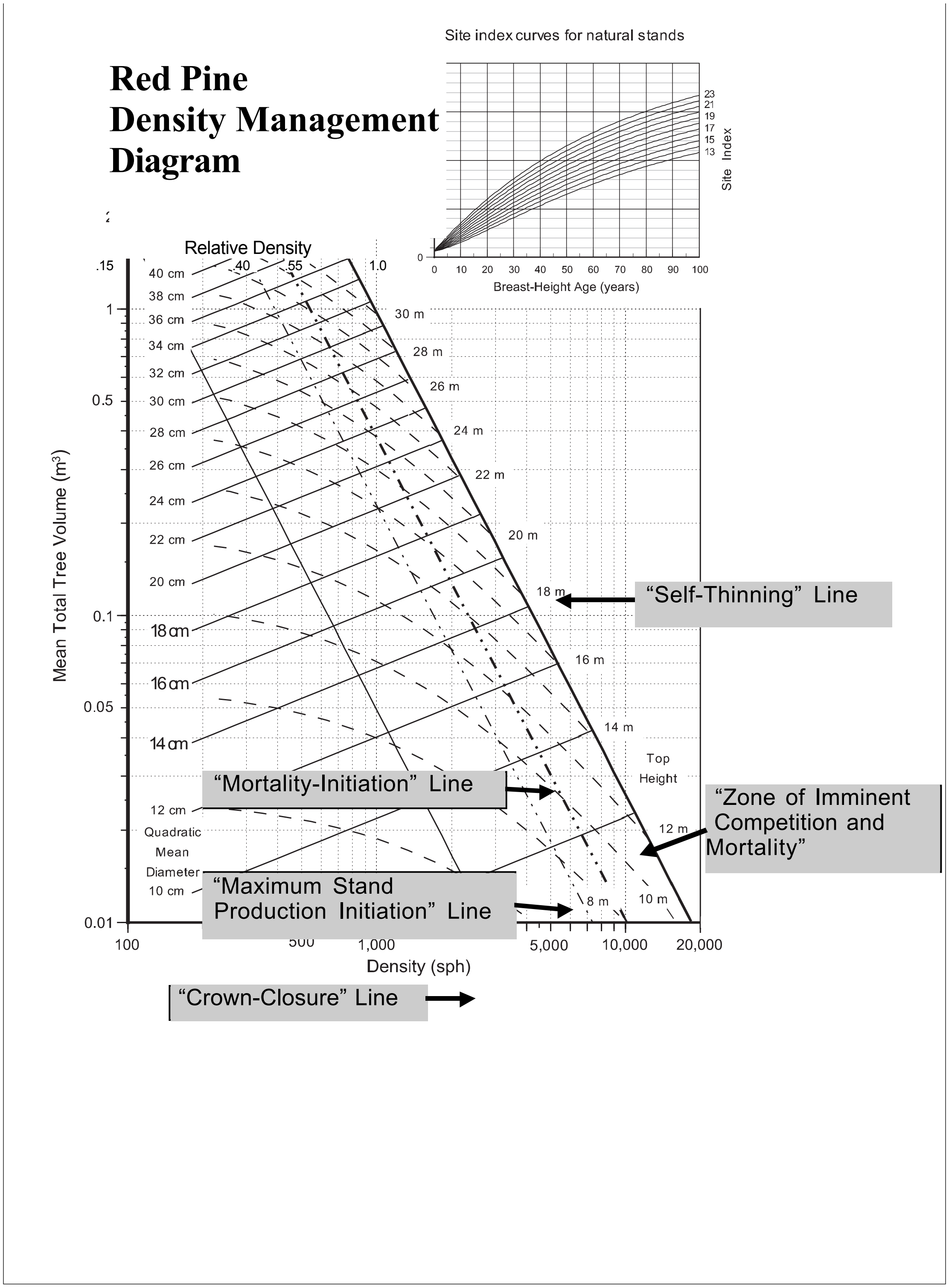
Density Management Diagrams (DMD) are based on the -3/2 power law of self-thinning. DMDs are considered average, age-independent, stand-level models which graphically illustrate the relationships between yield, density and mortality at various stages of even-aged stand development (Newton and Weetman 1993). In addition, they are also thought to be site-independent. The DMD is a stocking guide for even-aged single-species stands that illustrates the dynamic nature of stand development (Matson 1991; Archibald and Bowling 1995; Smith and Woods 1997). This dynamic relationship can be managed, through planned stand thinnings, to enhance the volume production of a stand or to influence the final dimension of residual stems. This can be achieved by determining an optimum stand establishment density or by carefully planning and timing thinning operations.

The structure of the modern day DMD (FIGURE 7.5.1) is based on early work by Reineke (1933) on stand density indices, Langsaeter (1941) on the relation of tree growth to stocking, Yoda *et al.* (1963) who investigated -3/2 self-thinning theory in relation to herbaceous plant communities, and Drew and Flewelling (1977, 1979) who transferred the self-thinning concept to forest tree species (***see*** APPENDIX G - Instructions on how to use a DMD to develop spacing and thinning prescriptions).

The X-axis represents stand density expressed as stems per hectare (sph), and the Y-axis is mean total tree volume in cubic metres (m^3). Four parallel density-dependent lines are shown: the self-thinning, mortality initiation, maximum stand production initiation and crown closure lines. The "self-thinning" line (relative density of 1.00) defines the upper boundary for any combination of mean size and stand density. Theoretically, stand development trajectories cannot exist beyond this line. The "crown-closure" line (relative density of 0.15) defines the boundary where stands have achieved crown closure and trees start competing with each other for available resources. Competition-induced mortality becomes critical once a stand transects the "mortality-initiation" line (relative density of 0.55) and grows toward the self-thinning line. Because the maximum amount of mortality occurs between these lines, this area of the diagram is often referred to as the "Zone of Imminent Competition and Mortality (ZICM)". Maximum stand growth (based on Langsaeter 1941) is realized just below the lower boundary of the ZICM and above the maximum stand production initiation line (relative density of 0.40). When possible, stands should be successively thinned between the 0.40 relative density line and the 0.55 ZICM line throughout their rotation to ensure maximum stand growth.

The DMD is a management tool that helps the forest manager examine the stand development relationships that exist between density, mortality and yield. If the aim in developing a prescription is to maximize stand volume growth, any loss of volume or reduction of stand growth is undesirable and a thinning schedule that can optimize volume growth is a desirable objective. With the DMD the manager is able to plan thinning schedules (using a "low" or "thinning from below" approach) and estimate gains in stand mean diameter by plotting, and then examining various thinning scenarios. An example on how to use a density management diagram for the development of a thinning strategy is presented in APPENDIX G. Refer to Smith and Woods (1997) or Archibald and Bowling (1995) for more discussion and detail on thinning with DMDs.

FIGURE 7.5.1: Density management diagram



TYPES OF THINNING

Thinning practices may be either selective or systematic.

Selective thinning refers to the removal or retention of trees based on their individual merits.

Systematic thinning removes trees according to a predetermined system that does not permit consideration of the merits of individual trees (Rollinson 1988). TABLE 7.5.3 provides an overview of these practices, methods and management implications. In most situations a combination of the methods is employed throughout the rotation of a stand.

THINNING INTENSITY

Thinning intensity is commonly presented as the basal area removed and is usually expressed as a percentage. It should not be confused with the thinning yield which is the actual volume removed in any one thinning. Over a wide range of thinning intensities the cumulative gross total volume production is unaffected. At low thinning intensities, stands will still be overstocked, unless the initial planting spacing was very wide, and the cumulative gross total production is reduced because some trees will die before they are harvested. At high intensities, stands do not fully utilize the growing space created by the thinnings, so that cumulative production is reduced.

The choice of thinning intensity depends on the location of the stand, the markets available, and the long term objectives (timber, wildlife, etc.) for the stand. Higher intensities will be reflected in greater increases in mean diameter of the main crop trees. In addition, the greater thinning yields (gross merchantable volume) resulting from higher intensities provide greater revenues. Taken together, these features tend to make higher thinning intensities more profitable, although the reduced volume of the final crop has to be taken into account. The marginal thinning intensity is often chosen as it produces the highest possible thinning yields without reducing the total volume production over the rotation, but there are circumstances when it will not be the best choice. If thinnings are difficult to sell, thinning may not be undertaken, or a lower thinning intensity adopted. If large sized trees are required as soon as possible, a higher thinning intensity may be adopted even though total volume production will be reduced (Rollinson 1988).

TIMING OF THINNING

Timing of initial thinning operations varies by species, site quality, spacing, thinning intensity, harvesting and marketing conditions. Timing of thinning of white pine is less critical than for red pine due to its greater shade tolerance and its greater capacity for crown canopy differentiation (Chapeskie 1983; Cooke and Barrett 1985; OMNR 1996). However, if white pine is not thinned there is steady mortality of codominant and lower crown classes and diameter growth is greatly diminished (Stiell 1979; Cooke and Barrett 1985; Leak 1985). If red pine is left unthinned,

TABLE 7.5.3: Common thinning methods (*from*: Daniel *et al.* 1979)					
THINNING PRACTICE	THINNING TYPE	THINNING OBJECTIVE	THINNING METHODS	THINNING PHILOSOPHY	MANAGEMENT IMPLICATIONS
Selective Thinning	"Thinning from Below" or "Low Thinning"	Release the dominant and codominant trees.	Trees are removed from the lower canopy. These trees tend to be the smaller diameter suppressed and sub-dominant trees.	Benefits dominant and codominant trees by removing smaller and weaker stems that are using significant amounts of water and nutrients. This type of thinning can be made throughout the rotation of the stand.	Depending on the initial density and timing of thinning, marketability of the material may be limited in early thinnings.
	"Thinning from Above" or "High" or "Crown" Thinning	Release the dominant and good codominant trees.	Trees are removed from the dominant and codominant canopy to space the potential crop trees. Suppressed and trees likely to die before the next thinning are also removed.	Lower crown classes are using insignificant amounts of nutrients. Competition is between the dominants and codominants. This type of thinning cannot be maintained throughout the rotation of the stand.	More immediately profitable than low thinning, but has a higher potential for causing felling damage to smaller future crop trees. Potential total volume yield over the rotation is lower than thinning from below.
Systematic Thinning	"Row" or "Strip" or "Chevron" Thinning	Provide relatively inexpensive access to plantations or stands for future selective thinning. Used for initial and potentially second thinning operations.	Rows or strips of trees are removed (by chainsaw or mechanically) regardless of individual tree characteristics.	A method of performing an inexpensive thinning treatment if the savings in cost is greater than the likely loss of future revenue from selective thinning methods.	Systematic thinning without successive selective thinning reduces total yield proportional to the intensity of thinning. Has negligible effect on average stand diameter following a thinning, but does significantly increase the growth rate of the dominant trees.

diameter growth is greatly reduced, and it will develop tall, spindly stems that are susceptible to storm damage. Response of stands in this stage of development is minimal and thinning prescriptions should be tailored (reduced below recommended) to account for poor stem development.

Density management diagrams allow resource managers to forecast required thinning time-frames based on initial spacing and site quality (e.g. site index). TABLE 7.5.4 suggests when a first thinning should be conducted in red and white pine stands. It is based on the age at which stands intersect the ZICM (relative density of 0.55). This represents the optimum point at which to thin the stand to maintain maximum stand diameter growth while reducing the chance of competition induced mortality occurring. Standard thinning ages for other conifer species by site class (Plonski 1981) are given in TABLE 7.5.5.

The projected thinning age is later in more widely spaced stands. There are many circumstances where the most profitable treatment will be to thin later than the age recommended to maintain maximum diameter growth (TABLE 7.5.4 and TABLE 7.5.5), notably where the standing value of trees at this age may be low. This trade-off in timing a merchantable first thinning may have impacts on meeting future wood supply demands if thinning is greatly delayed. Studies have shown that delaying the first thinning is unlikely to cause a reduction in cumulative production of usable timber unless the thinning is delayed so long that trees start dying, but it will affect the mean diameter of the trees (Rollinson 1988). Where the first thinning is delayed, the stand will generally require a heavier thinning to return the stand to a desired stocking level. It may not be possible to do this in one operation if the thinning has been considerably delayed, as this could lead to loss of volume production or stand instability. Subsequent thinnings will also need to be heavier than normal to compensate. Using a DMD to plan initial stand densities (***see*** APPENDIX G) will permit the resource manager to project a likely stand trajectory, plan the timing of thinnings, and estimate the average extracted product dimensions (Matson 1991; Archibald and Bowling 1995; Smith and Woods 1997) to avoid these scenarios.

THINNING CONTROL

Thinning objectives can be expressed as the number of trees, basal area or volume to be removed (each component a part of a DMD). Control by number of trees is not recommended as the result of thinning is very dependent on the type of thinning. If the smallest trees are removed, the stand will be left much denser than if the same number of larger trees were removed.

Therefore, thinning should be controlled by basal area or volume, and this can be by the amount removed, or the amount remaining. Having control by the amount removed is preferable for four reasons:

- it is easier to implement
- it tends to produce a constant and predictable yield of timber that is useful for planning purposes
- it discourages drastic reduction of the level of the growing stock that can lead to windthrow or other damage caused by a sudden opening of the canopy.

It considerably reduces the effect of inaccurate site productivity assessment, which can occur if the local condition has not been measured.

TABLE 7.5.4: Recommended basal area and age for first thinning in red pine and white pine stands based on initial spacing and Site Index (*from*: Smith and Woods 1997)

Species	Spacing (m)	Density stems/ha	Basal Area (m^2/ha)	DBHq* (cm)	Top Height** (m)	Site Index 16	18	20	22	24	26	28
						Age						
red pine	1.8 x 1.8	3090	37.6	12.5	12.5	40	35	30	28	26	24	23
	2.0 x 2.0	2500	38.8	14.1	14.0	46	40	35	32	29	27	25
	2.2 x 2.2	2070	39.9	15.7	15.0	50	39	38	35	32	29	27
	2.4 x 2.4	1740	40.9	17.3	16.0	55	45	40	37	34	31	29
	2.6 x 2.6	1480	41.8	19.0	17.0	60	51	45	40	36	33	31
	2.8 x 2.8	1280	42.7	20.6	18.0	65	55	48	43	39	35	33
	3.0 x 3.0	1110	43.6	22.4	19.5	74	62	53	47	42	39	36
white pine	1.8 x 1.8	3090	18.4	8.7	14.5	46	37	31	27	24	22	20
	2.0 x 2.0	2500	20.3	10.2	15.5	52	41	35	30	27	24	22
	2.2 x 2.2	2070	22.2	11.7	17.0	65	50	39	34	30	27	24
	2.4 x 2.4	1740	24.0	13.3	18.0	77	56	45	38	33	29	26
	2.6 x 2.6	1480	25.9	14.9	19.0	94	64	50	42	36	32	28
	2.8 x 2.8	1280	27.7	16.6	20.0		74	56	46	39	34	30
	3.0 x 3.0	1110	29.6	18.4	21.0		88	63	51	43	37	33

*   DBHq - quadratic mean diameter
** Top Height- average height of largest 100 trees/hectare

TABLE 7.5.5: Standard thinning ages for other conifer species

SPECIES	SITE CLASS I	II	III
white spruce	30	35	40
red spruce	30	35	40
eastern white cedar	50	60	80

7.5.1.4 Stand improvement

Improvement cutting generally applies to high-graded stands, mixedwood stands, and occasionally to extensively managed plantations that are pole size and larger. Defective and overmature trees of any species are removed to favour future crop trees. Thinning of potential crop trees may be a component of improvement activity, depending on vertical structure and density of the stand. Where possible, commercial operations are favoured, although this strategy often requires delaying the treatment until white pine stands are 30 to 40 years of age and red pine stands are 25 to 30 years of age. Trees with larger, fuller crowns respond best.

White pine stands, particularly those containing a hardwood component, benefit most from improvement cutting (Stiell 1985). Improvement cutting in mixedwood stands has resulted in impressive growth and merchantable yield gains for both white pine and red pine (Stiell 1984). Results of economic analysis suggest those improvement operations in white pine and red pine stands are a wise investment (Vodak *et al.* 1981).

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8.0 Integrating Timber and Wildlife Habitat Management

8.0 Integrating Timber and Wildlife Habitat Management

by Brian J. Naylor

In the 1980s, timber management in Ontario focused on integrating the habitat needs of featured wildlife species. Featured species were those of special interest because they were hunted (e.g. moose) or were threatened with local extinction (e.g. bald eagle). In the 1990s, the management philosophy has shifted to embrace an ecosystem approach that stresses the maintenance of biodiversity and a concern for the habitat needs of all wildlife (Ontario Wildlife Working Group 1991).

A total of 305 species of amphibians, reptiles, birds and mammals inhabit the Great Lakes-St. Lawrence forest of central Ontario (Bellhouse and Naylor 1997). Of these species, 190 meet the majority of their life requirements in forest habitat; an additional 36 species live mainly in non-forested habitat but use riparian (shoreline) forest (e.g. beaver). One or more ecosites or development stages within the Great Lakes-St. Lawrence conifer forest represent preferred (i.e. highly suitable) habitat for about 130 forest-dependent species. About 60 more species make occasional use of Great Lakes-St. Lawrence conifer forest. No species is found only in the Great Lakes-St. Lawrence conifer forest. However, 3 species find preferred habitat only in the Great Lakes-St. Lawrence conifer forest (***see*** Bellhouse and Naylor 1997).

There is considerable variability in the degree to which species use Great Lakes-St. Lawrence conifer forest and in the specific needs of individual species. For example, species vary in terms of:

- seasons of use
- range of ecosites used
- range of development stages used
- size of habitat patches required
- interspersion of habitat patches required
- types of special habitat components needed (e.g. cavity trees, downed woody debris).

How can the habitat needs of all species using the Great Lakes-St. Lawrence conifer forest be satisfied, given the large number of species and the tremendous variety of requirements? The evolving approach in Ontario stresses the use of a combined *coarse* and *fine* filter methodology (***see*** Hunter 1990). The *coarse filter* approach focuses on maintaining habitat diversity through space and time and assumes that this will provide habitat for most wildlife species. The *fine filter* approach focuses on the provision of habitat for species of special concern.

8.1 The Coarse Filter

The coarse filter approach attempts to maintain a diversity of habitats for wildlife at a variety of spatial scales through time. Wildlife habitat can be defined at an infinite number of spatial scales. To implement the coarse filter, planning for a diversity of wildlife habitats should be conducted at a broad landscape scale (100,000s ha [i.e. management units (MUs) or portions of MUs]). Silvicultural practices should be modified at both 1) the stand or operating block scale (10s to 100s ha) to create a diversity of habitat conditions within stands being harvested and 2) at the site scale (< 10 ha) to protect special habitat features associated with specific geographic locations.

8.1.1 Landscape Scale

ECOSITES AND DEVELOPMENT STAGES

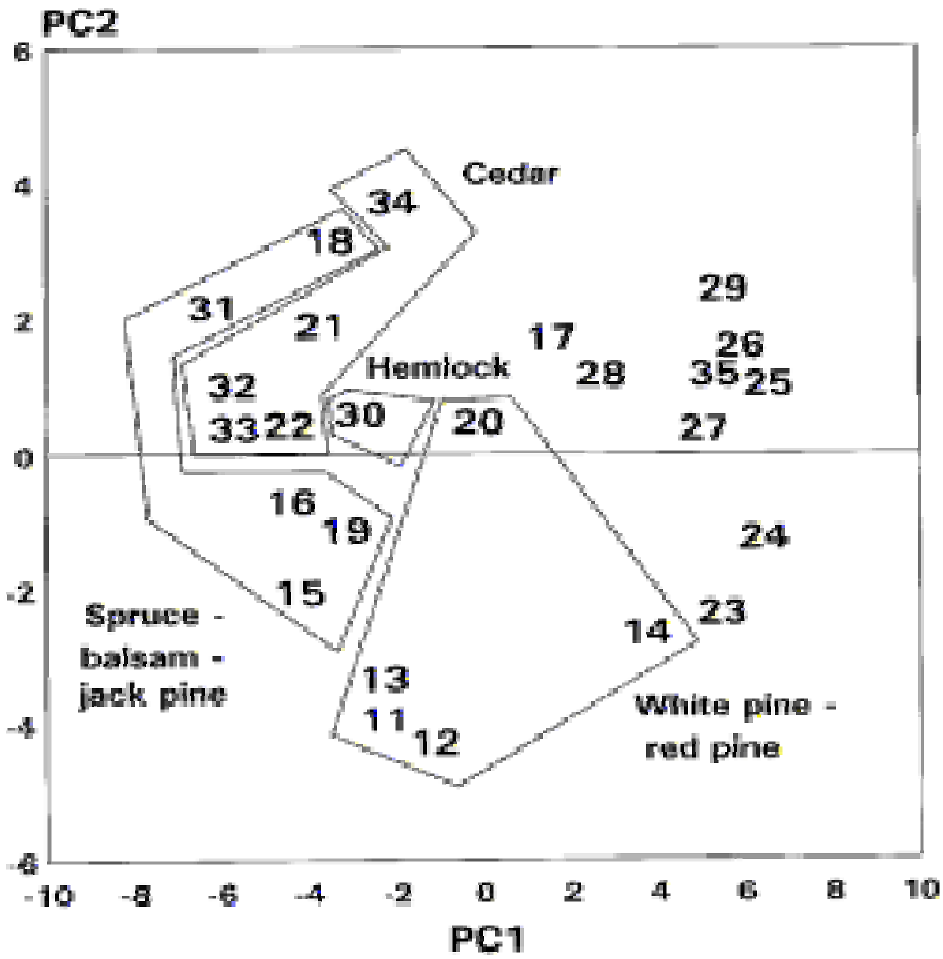
FIGURE 8.1 illustrates the relationship among the 25 ecosites found in the Great Lakes-St. Lawrence forest of central Ontario based on the similarity of their wildlife communities. Great Lakes-St. Lawrence conifer ecosites tend to be distinct from those dominated by intolerant hardwoods (ES 17) or tolerant hardwoods (ES 23 to 29 and 35) (with the exception of white pine-poplar- red oak ecosites [ES 14]). Thus, the first step in managing habitat for wildlife that use the Great Lakes-St. Lawrence conifer forest requires application of silvicultural practices that ensure this forest type is perpetuated across the landscapes of central Ontario.

Within the Great Lakes-St. Lawrence conifer forest, wildlife communities are very similar among some ecosites (e.g. ES 11 to 13) (FIGURE 8.1). However, wildlife communities differ substantially among others (e.g. ES 11 to 13 *vs*. ES 32 to 34). Moreover, individual ecosites differ in the number of species that use and/or prefer them (TABLE 8.1). Thus, silvicultural practices applied in central Ontario should perpetuate as great a diversity of Great Lakes-St. Lawrence conifer ecosites as possible.

Development stage is also an important factor influencing use of the Great Lakes-St. Lawrence conifer forest by some species. Of the wildlife that use Great Lakes-St. Lawrence conifer ecosites, around 20 per cent are found only in immature forest (pre-sapling to polewood stages) and up to 10 per cent are found only in mature forest (TABLE 8.1). However, less than 10 per cent of the wildlife that only use immature forest prefer Great Lakes-St. Lawrence conifer ecosites (i.e. most species that need immature forest prefer other forested or non-forested habitats). In contrast, about 90 per cent of the species that only use mature forest prefer Great Lakes-St. Lawrence conifer ecosites. Thus, managers should attempt to create a diversity of age classes within the Great Lakes-St. Lawrence conifer forest but should recognize that mature forest is especially important.

How much of each ecosite (or group of similar ecosites) or development stage is needed on Great Lakes-St. Lawrence forest landscapes to meet the needs of all wildlife species? This question can be answered for a few individual species for which there is considerable knowledge (e.g. moose or deer) but there is no simple answer when all species are considered. However, it is reasonable

FIGURE 8.1: Ordination of central Ontario ecosites based on principal components analysis of wildlife communities described in Bellhouse and Naylor (1997). Numbers refer to ecosite types. Polygons enclose ecosites dominated by white pine-red pine, hemlock, cedar, or spruce -balsam- jack pine. PC1/PC2 represent ecosite loadings on the first 2 principal components (explaining 49 per cent of the total variance)



to assume that the landscape scale needs of most wildlife will be satisfied if forest management can maintain, within practical bounds, a landscape with roughly the same mix of ecosites and age classes (in appropriate patterns) that occurred in the "natural" presettlement forest (***see*** Hunter 1990) (this assumes that wildlife have adapted to the composition and structure of the forested landscape that has developed during the 10,000 years since the last glaciation).

To set targets for a landscape with a "natural" level of diversity requires information on the composition and structure of the presettlement forest. Some guidance for managers follows.

TABLE 8.1: Number of species of amphibians, reptiles, birds and mammals using Great Lakes-St. Lawrence conifer ecosites in central Ontario and various habitat components within these ecosites (*based on:* Bellhouse and Naylor 1997)								
Ecosite	Total No. of Species[1]	Immature Forest[2]	Mature Forest[3]	Cavity Users	DWD Users	Mast Users	Conifer Users	Riparian Users
ES 11	136 (54)	24 (2)	7 (6)	32	57	32	2	52
ES 12	142 (55)	28 (2)	7 (6)	33	58	31	3	52
ES 13	134 (56)	25 (2)	6 (6)	32	55	31	3	51
ES 14	151 (59)	33 (2)	15 (12)	41	60	42	8	53
ES 16	137 (54)	28 (2)	6 (5)	33	55	34	2	52
ES 18	143 (53)	26 (2)	7 (6)	34	63	37	4	56
ES 19	128 (41)	28 (1)	6 (5)	30	51	31	4	46
ES 20	152 (56)	33 (1)	8 (7)	37	66	35	6	58
ES 21	146 (48)	28 (2)	7 (6)	36	63	37	4	58
ES 22	143 (50)	24 (2)	8 (7)	35	59	38	2	55
ES 30	135 (53)	20 (1)	7 (7)	31	58	32	3	53
ES 32	120 (38)	18 (1)	7 (6)	27	49	30	2	51
ES 33	143 (51)	24 (2)	8 (7)	35	59	38	2	55
ES 34	139 (53)	25 (2)	9 (8)	38	66	38	5	62

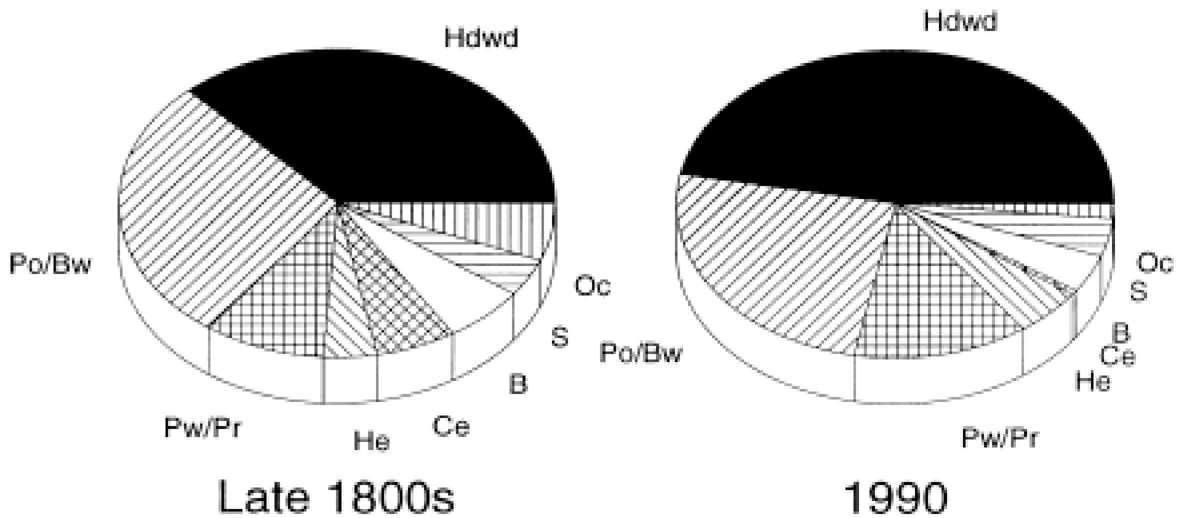
[1] Number of species for which ecosite is preferred habitat in brackets. Note: there is considerable species overlap among ecosites.

[2] Number of species using only forest in the pre-sapling, sapling, or polewood development stages. Number of species for which ecosite is preferred in brackets.

[3] Number of species using only forest in the mature or old development stages. Number of species for which ecosite is preferred in brackets.

Some information on the mix of ecosites on historic landscapes can be obtained from analysis of Crown land survey records. For example, analysis of these records for 10 townships (2,560 km^2) in central Ontario (surveys conducted in 1863 to 1890) suggests that the area of pine, hemlock, balsam and spruce-dominated forest within these townships has remained relatively constant or increased during the past 100+ years, but that the area of cedar-dominated forest has declined dramatically (FIGURE 8.2).

FIGURE 8.2: Comparison of the area of pine (Pw/Pr), hemlock (He), cedar (Ce), balsam (B), spruce (S), other conifers (OC), intolerant hardwood (Po/Bw) and tolerant hardwood (Hdwd) dominated forest in the late 1800s and in 1990 in 10 townships from central Ontario. Composition from the late 1800s is based on analysis of Crown land survey records (Naylor *unpubished data*). Composition in 1990 is from the Ontario Forest Resources Inventory.



This small sample cannot be extrapolated to the entire Great Lakes-St. Lawrence forest region. Moreover, survey records cannot be used to set precise targets for the desirable area of each ecosite, working group, or forest unit because they represent a single view of the presettlement forest and are themselves biased by some European intervention (e.g. land surveys generally followed the initial period of white pine extraction). However, managers should strive to acquire locally relevant information which can be interpreted within the context of the dynamics of these systems and historic activities to set some general direction. For example, a forest manager faced with the information in FIGURE 8.2 should try to adjust management activities to: 1) at least perpetuate the remaining cedar forest on the management area and 2) where feasible, increase the amount of cedar in ecosites where it may not currently, but could be, a major component (e.g. ES 21, 22 and 32 to 34).

A rough estimate of the mix of age classes in the presettlement forest can be obtained from theoretical models that predict age class structure based on knowledge of historic disturbance regimes (***see*** review in Li *et al.* 1996). The simplest of these is the negative exponential model proposed by Van Wagner (1978). It assumes that stand-replacing disturbances affect stands of any age and that an equal area is disturbed every fixed time interval (e.g. 20 years). These assumptions (which are not entirely valid) lead to a predicted landscape with a stable age class structure following an inverse J-shaped curve. The slope (steepness) of the curve reflects the frequency of stand-replacing events (*the disturbance cycle*).

In the Great Lakes-St. Lawrence conifer forest, both catastrophic wind and wildfire appear to have been stand-replacing agents. In pine-dominated and mixedwood forest, fire seems to have been the primary disturbance agent (***see*** Heinselman 1981; Whitney 1986). For pine forest, the disturbance cycle has been reported as 70 years in Algonquin Park (Cwynar 1977), 105 years in Temagami (calculated from data in Day and Carter 1990), 126 to 253 years in Michigan (Whitney 1986) and 150 to 180 years in Minnesota (Frissell 1973; Heinselman 1981). For mixedwood forest in which spruce, balsam and/or jack pine were the dominant conifers, the disturbance cycle was likely about 80 years (Heinselman 1981).

In cedar and hemlock-dominated forest, wind may have been the primary disturbance agent. For example, in lowland cedar forest in Michigan, the disturbance cycle for stand-replacing wind events (severe thunderstorm downdrafts, hurricanes and tornados) was 1,316 to 2,632 years while the cycle for stand-replacing fires was 2,959 to 5,917 years (Whitney 1986). Whitney (1986) suggested a combined wind/fire cycle of 907 to 1,813 years. The disturbance cycle for hemlock forest was likely similar to that for tolerant hardwood forest (combined wind/fire cycle around 1,000 years; ***see*** Canham and Loucks 1984; Whitney 1986; Frelich and Lorimer 1991). Given this similarity and the relatively small area of hemlock forest in each management area (the assumptions of the negative exponential are more nearly approached when large landbases are used), hemlock and tolerant hardwood ecosites should be combined when age class modelling is conducted (***see*** Section 2.8 “Habitat Management Considerations” in *A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario*).

FIGURE 8.3 illustrates an age class distribution predicted by the negative exponential model for pine-dominated ecosites using a 100 year fire cycle. The x-axis in FIGURE 8.3 represents time since the last stand-replacing disturbance. It does not necessarily represent the age of the dominant/codominant trees in the overstory. For example, pine stands in the 0 to 20 year “age class” may have experienced a stand-replacing understory fire that left a partial overstory of mature trees. Moreover, the right-hand tail of the negative exponential distribution stretches to infinity because some small portion of the forest would theoretically never be affected by fire. However, in the absence of a stand-replacing disturbance, mature pine stands will eventually convert to a younger age class of dissimilar forest type (e.g. Heinselman 1973).

Information from theoretical modelling such as presented in FIGURE 8.3 can be used to help set some general targets for age class structure in the Great Lakes-St. Lawrence conifer forest. For example, there is considerable debate about how much “old growth” pine forest (i.e. pine forest > 120 years of age) should be retained on Great Lakes-St. Lawrence forest landscapes (Old Growth Policy Advisory Committee 1993). If old growth is defined as forest that has not experienced a stand-replacing disturbance for 120+ years, FIGURE 8.3 might be used to set a general objective.

FIGURE 8.3: Theoretical age class distribution predicted for pine ecosites based on the negative exponential model (fire cycle of 100 years)

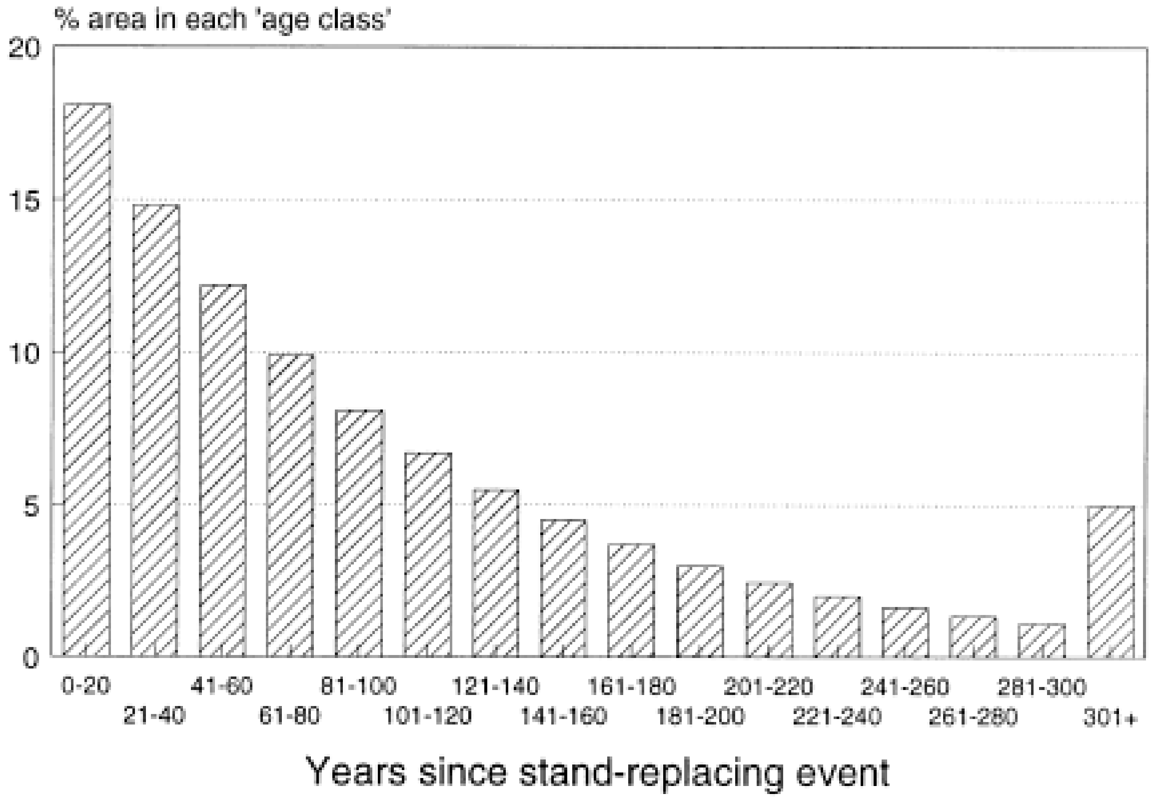


FIGURE 8.3 suggests that in a theoretical equilibrium landscape, about 30 per cent of the pine forest would not have experienced a stand-replacing disturbance within the previous 120 years. However, about 17 per cent these older stands would have escaped a stand-replacing disturbance for 300+ years and might no longer be dominated by pine. Thus, about one-quarter of the area of forest actually dominated by pine would have escaped a major disturbance within the past 120 years. Using this as a rough guide, a manager might try to retain somewhere around 25 per cent of the pine forest in stands 120+ years of age. Stands receiving a shelterwood seeding cut would not contribute to this 25 per cent target (even if they have a residual overstory 120+ years) because these stands would be considered to have experienced a stand-replacing disturbance. However, old pine stands in protected areas could contribute to this target.

When using disturbance models such as proposed by Van Wagner, it is important to remember that they generate age class structures that are abstractions of reality. Forested landscapes would rarely be in an equilibrium or steady-state condition. Thus, results produced by these models should be viewed as providing broad, rather than precise, targets for areas occupied by each forest age class.

The area of different ecosites and age classes on a landscape under a natural disturbance regime can be estimated through simulation modelling. For example, the Strategic Forest Management Model (SFMM; Davis 1996) can be used to project the area of ecosites and age classes through time based on rule sets describing natural disturbance frequency and rates of natural succession. The Ontario Fire Regime Model (ONFIRE; Li *et al.* 1996) can also be used to project age class distributions through time.

LANDSCAPE PATTERN

Landscape pattern is another important factor to consider when managing habitat for wildlife (Hunter 1990). Some species are thought to be area-sensitive and may need large blocks of forest (e.g. pileated woodpecker), others do best with small patches and lots of edge (e.g. deer) while others need a complex mosaic of forest types and ages within their home ranges (e.g. moose). Thus, the design of operating blocks should attempt to emulate variation in the characteristics of natural disturbance patches such as size, shape, amount of edge, and amount and type of residual patches, and should be dispersed to, as much as possible, emulate the interspersion of young and mature forest on 'natural' landscapes.

Clearcut and shelterwood operating blocks should attempt to emulate the characteristics of catastrophic wind events (blowdowns) or wildfires. Some direction for clearcuts may be obtained from the *Forest Management Guidelines for the Emulation of Fire Disturbance Patterns* (OMNR *in prep*.), although these guidelines were primarily designed for boreal-type forests.

Managers should also use any local information available to help set targets (e.g. analysis of aerial photographs of recent blowdowns or wildfires in the Great Lakes-St. Lawrence conifer forest). In addition, some information is available from the published literature. For example, Canham and Loucks (1984) analyzed land surveys conducted in the mid 1800s in Great Lakes-St. Lawrence forest in northern Wisconsin. They found that the proportion of area blown down by size class was: 2 per cent in patches < 10 ha, 15 per cent in patches 11 to 100 ha, 41 per cent in patches 101 to 1,000 ha and 42 per cent in patches > 1,000 ha (maximum patch size was 3,785 ha).

Thirty years of data on blowdowns in Algonquin Park, Ontario, further supports the contention that blowdowns are generally large; 1 per cent of area in patches < 100 ha, 17 per cent of area in patches 100 to 1,000 ha and 82 per cent of the area in patches > 1,000 ha (OMNR *unpublished data*). Thus, some large contiguous or progressive clearcuts or shelterwood cuts in cedar or hemlock forest would not be inconsistent with the pattern of natural disturbances.

Canham and Loucks (1984) also provide some information on the shape of blowdowns. Transects of early land surveyors crossing blowdowns ranged from 60 to about 4,000 m in length. However, most blowdowns were long and narrow, with about 25 per cent of patches < 100 m wide, about 60 per cent of patches < 250 m wide and about 75 per cent of patches < 400 m wide.

Unfortunately, there is very little information on other characteristics of blowdowns or on most characteristics of wildfires in the Great Lakes-St. Lawrence conifer forest. However, "typical" pine fires have been reported as 40 to 400 ha by Heinselman (1973) and 400 to 4,000 ha by Frissell (1973). In the absence of better data, a manager might follow the general pattern of disturbance patches outlined for site regions 4E and 5E in the *Forest Management Guidelines for the Emulation of Fire Disturbance Patterns* (OMNR *in prep*.). In addition, patch size distribution and dispersion may be estimated from simulation modelling using ONFIRE (Li *et al.* 1996).

8.1.2 Stand Scale

The diversity of wildlife found in individual stands (or blocks of stands) is affected by numerous factors that contribute to the diversity of the stand's composition and structure (Hunter 1990). Important features to consider during management in all Great Lakes-St. Lawrence conifer ecosites are: tree species diversity (including mast trees and scattered hardwoods), canopy structural diversity, cavity trees, downed woody debris and supercanopy trees.

TREE SPECIES DIVERSITY

The number of wildlife species using a stand is generally related to the diversity of trees in the overstory (e.g. Menard *et al.* 1982).

Managers should strive to maintain and perpetuate a mix of species within each stand through time that reflects the site conditions, the prevailing species association and the stand dynamics. Thus, management objectives for each stand should address targets for species diversity in 1) the residual overstory and 2) the future overstory.

While targets for the composition of the future overstory will incorporate socio-economic considerations, they should also be based on sound ecological rationale. This should include a consideration of the biological suitability of each species (***see*** Section 3.5 "Silvics") and also information on the historic diversity of the forest. For example, further analysis of Crown land survey records for the townships described in FIGURE 8.2 suggests that the composition of pine-dominated forest has changed during the past 100+ years (FIGURE 8.4). There appears to have been an increase in the proportion of intolerant hardwoods and a decrease in the amount of hemlock. Moreover, while the total amount of pine appears to have remained stable there may have been a shift in the relative amount of red and white pine. A manager faced with this kind of information should strive to implement management activities that will 1) maintain hemlock on sites where it is mixed with pine and 2) perpetuate red pine on appropriate sites. In the latter case, this may involve incorporating small patch cuts into the shelterwood harvest of mixed white pine-red pine stands.

In some cases there may be a strong ecological rationale to reduce the overstory diversity of stands. For example, conversion of a mixed pine-poplar stand to a relatively pure pine stand would likely be acceptable given diversity considerations at the stand and landscape levels.

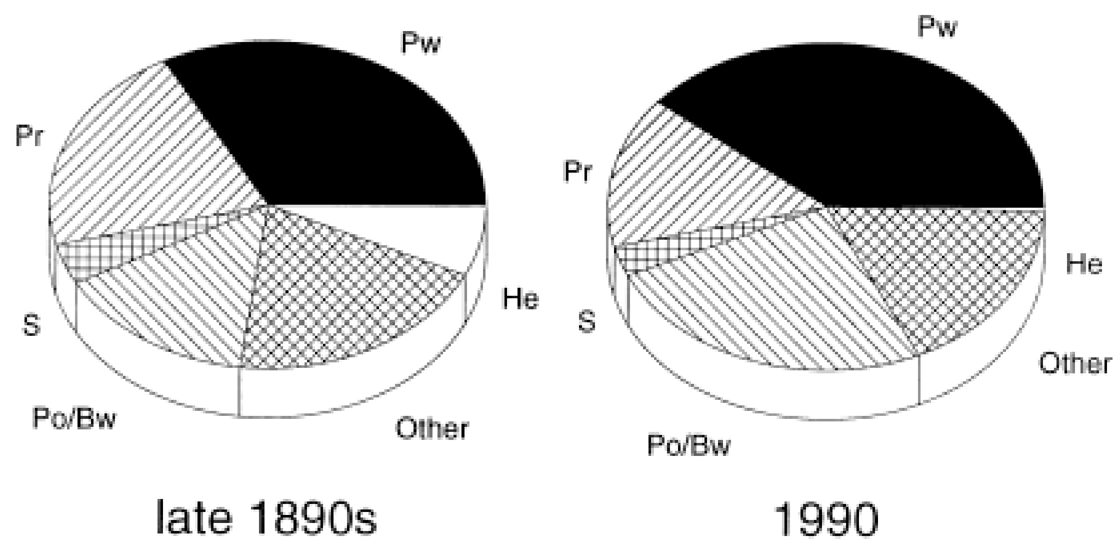
Diversity of the residual stand will be at least partly dictated by composition objectives for the future stand (e.g. regenerating pine in a mixed pine-poplar stand may require a large increase in the proportion of pine in the residual overstory). However, within the bounds imposed by the future objectives (including tree species diversity), the tree species diversity of the residual stand should, as closely as possible, reflect the diversity of the stand before cutting.

While all tree species contribute to stand diversity, two groups of tree species (mast trees, scattered hardwoods) have special importance to wildlife and are discussed in more detail below.

MAST TREES

About 25 per cent of the wildlife that inhabit Great Lakes-St. Lawrence conifer ecosites consume edible fruits (mast) produced by trees (TABLE 8.1). Availability of these foods can have important implications for wildlife. For example, the abundance of mast influences weight gain, reproductive rate and cub survival in black bears (Rogers *et al.* 1988).

FIGURE 8.4: Relative basal area of hemlock (He), white pine (Pw), red pine (Pr), spruce (S), intolerant hardwoods (Po/Bw) and other species in the late 1800s and in 1990 in pine-dominated forest for the area described in FIGURE 8.2. Composition from the late 1800s is based on analysis of bearing trees in Crown land survey records (Naylor *unpublished data*). Composition in 1990 is from the Ontario Forest Resources Inventory



Oaks, American beech, black cherry, basswood and ironwood are important mast-producing trees found in the Great Lakes-St. Lawrence conifer forest (Tubbs *et al.* 1987). Red oak is a common component of ES 14 and is occasionally found in ES 11 to 13, 22 and 30. The other species occur infrequently in ES 11 to 14, 18, 20, 22, 30 and 34. When stands contain mast trees, current guidelines (adapted from Naylor 1994a) recommend:

- retention of a minimum of 7 to 8 good mast producers per ha in all ecosites

- retention of species in the following order of priority: oaks, beech, black cherry, basswood and ironwood

- retention of trees at least 25 cm DBH (preferably 40 to 60 cm DBH) (ironwood will rarely meet this criterion but is a valuable species to leave)

- retention of trees with large, vigorous, well-rounded crowns.

ES 14 can have a large red oak component. These ecosites may be extremely important mast-producing areas for wildlife such as deer and black bears. When mast-producing areas are relatively scarce, managers may elect to manage these sites to enhance and perpetuate the oak component, especially if within 2 km of a deer yard (Voigt *et al.* 1997). However, these decisions must be consistent with the overall objectives for landscape diversity (***see*** "ECOSITES AND DEVELOPMENT STAGES" in Section 8.1.1 "Landscape Scale") and tree species diversity (***see*** above).

Mast-producing shrubs such as raspberries, blueberries, cherries, serviceberries and hazels are also important components of wildlife habitat, especially on recently disturbed sites. Site preparation and tending activities can influence the abundance of many species of mast-producing shrubs (Balfour 1989; McMillan *et al.* 1990). Thus, managers should understand how their practices affect these species and attempt to prescribe activities that minimize impacts.

SCATTERED HARDWOODS

Declining hardwoods generally represent the best cavity trees available in the Great Lakes-St. Lawrence conifer forest. Important mast-producing trees are all hardwoods. Moreover, up to 5 per cent of wildlife in the Great Lakes-St. Lawrence conifer forest require hardwood trees for some other aspect of their life history (e.g. species may nest only in hardwood trees). Thus, scattered hardwood trees are an important habitat component of all Great Lakes-St. Lawrence conifer ecosites and some should be retained in all stands.

CANOPY STRUCTURAL DIVERSITY

The number of wildlife species using a stand may also be influenced by both the vertical and horizontal structural diversity of the tree canopy (MacArthur and MacArthur 1961; Roth 1976). Vertical diversity reflects the number of canopy layers in the stand. Horizontal diversity is an expression of the patchiness of tree boles and canopy gaps.

Selection and initial shelterwood cuts tend to produce stands with high vertical diversity. Vertical diversity can be further enhanced by following guidelines for the retention of supercanopy trees (***see*** "SUPERCANOPY TREES" below). Retention of cavity trees (***see*** "CAVITY TREES" below), supercanopy trees and veterans or standards will increase vertical diversity in shelterwood removal cuts and clearcuts (***see*** Section 7.2.4.3 "Maintenance of the Structural Legacy of the Initial Forest").

Textbook application of silvicultural systems will generally produce stands with relatively low horizontal diversity. Horizontal diversity can be enhanced by:

- leaving some residual trees in clumps in stands receiving a shelterwood seeding cut

- leaving some scattered patches of residual overstory in removal cuts and clearcuts (***see*** *Forest Management Guidelines for the Emulation of Fire Disturbance Patterns* [OMNR, *in prep.*] for a discussion of the size and area of residual patches in natural disturbances)

- leaving some unprepared sites during site preparation activities.

CAVITY TREES

About 25 per cent of the wildlife that inhabit Great Lakes-St. Lawrence conifer ecosites use holes (cavities) in trees for rearing young, roosting, escaping predators, or hibernating (TABLE 8.1). Woodpeckers, black-capped chickadees and red-breasted nuthatches excavate their own holes and are termed *primary cavity users*. The remaining species (called *secondary cavity users*) do not excavate holes but rely on those created by primary cavity users or those that form as a result of natural decay processes (Tubbs *et al.* 1987).

Cavities are either excavated or form as the result of natural decay in dead or declining trees. Numerous studies indicate a positive relationship between the supply of cavities and the abundance of cavity users (Dickson *et al.* 1983; Land *et al.* 1989; Stribling *et al.* 1990). Management activities in the Great Lakes-St. Lawrence forest can have a negative effect on the supply of habitat for cavity users because 1) dead trees may be knocked down to comply with occupational health and safety legislation and 2) declining trees may be preferentially removed to meet silvicultural objectives (Healy *et al.* 1989). For example, in a recent study in Algonquin Park, uncut pine forest had about twice as many standing dead trees per hectare and twice as many trees with cavities per hectare as stands that had received a shelterwood seeding cut within 10 years (Kirk and Naylor, *in prep.*).

To mitigate potential negative impacts on cavity supply, current guidelines recommend the retention of at least 6 trees with cavities or the potential to produce cavities per hectare in all operating blocks in the Great Lakes-St. Lawrence forest (Naylor *et al.* 1996). In selection and shelterwood preparatory or seeding cuts, the guidelines suggest retaining cavity trees with immediate value to a broad range of cavity users, especially pileated woodpeckers (a featured species). Thus, the guidelines specify that cavity trees be retained in the following order of priority:

- pileated woodpecker roost and nest trees
- trees with nest cavities made by other woodpeckers or natural nest or den cavities
- trees with escape cavities
- trees with feeding excavations
- trees with the potential to develop cavities.

Refer to Naylor *et al.* (1996) for a description of these different types of cavity trees.

In clearcuts and shelterwood removal cuts, the guidelines suggest retaining cavity trees that have immediate value to cavity users of early successional forest (e.g. northern flicker, eastern bluebird) and those that will develop into cavity trees as the regenerating stand matures. Thus, retention of a mix of trees with cavities and with the potential to develop cavities is suggested. For trees with cavities, priority of retention is: trees with 1) nest cavities made by woodpeckers or natural nest or den cavities, 2) escape cavities and 3) feeding excavations.

To meet worker safety concerns, the guidelines recommend that cavity trees to be retained should be living and without obvious safety hazards (e.g. large dead limbs). As an exception, the guidelines suggest retaining dead trees with pileated woodpecker roost cavities in selection and shelterwood preparatory or seeding cuts. When dead trees are retained, they must have a tree length reserve placed around them.

Other characteristics to consider when retaining cavity trees include size, species, dispersion and multiple benefits. These attributes are discussed in detail in Naylor *et al.* (1996).

Retaining living cavity trees may not meet the requirements of all species that use dead and declining trees. For example, black-capped chickadees only excavate nest cavities in dead trees and brown creepers place their nests behind loose pieces of bark attached to dead trees (Peck and James 1987). Some living cavity trees will die and become snags. However, they will not likely compensate for the large number of dead trees that are felled to comply with health and safety legislation. Workers should be required to fell snags when they are a safety risk as defined by the Occupational Health and Safety Act (RSO 1990). However, standing dead trees that do not pose a potential safety risk should be retained whenever possible by operators during harvest and site preparation activities. In all cases, retention of standing dead trees should be at the discretion of the forest worker.

DOWNED WOODY DEBRIS

Over 40 per cent of the wildlife that inhabit Great Lakes-St. Lawrence conifer ecosites use logs, branches, or stumps on the forest floor (TABLE 8.1). Downed woody debris (DWD) provides feeding sites for pileated woodpeckers, plucking sites for northern goshawks, display sites for ruffed grouse, cover from predators for red-backed voles, travel routes for deer mice, moist microsites for spotted salamanders, nesting sites for red-backed salamanders, winter resting sites for American martens, maternal den sites for fishers, and hibernation sites for black bears (Bellhouse and Naylor 1996). The supply of downed woody debris has been linked to habitat use in pileated woodpeckers (e.g. Renken and Wiggers 1989) and American martens (e.g. Bowman 1996).

Forest management practices may affect the amount, condition, dispersion, or timing of recruitment of DWD (Bellhouse and Naylor 1996). However, in the short term, shelterwood management appears to have a minimal negative impact on the supply of DWD. For example, in Algonquin Park, stands with shelterwood seeding cuts up to 20 years old had as much DWD as uncut stands, even when size and decay condition were considered (Kirk and Naylor *in prep.*). Although shelterwood harvest removes many declining trees before they have a chance to die and become DWD, large limbs from felled trees, inputs of DWD from post-logging mortality, and felling of standing dead trees during harvest operations appears to more than compensate for this loss.

However, since the long term impact of forest management on the supply of DWD in the Great Lakes-St. Lawrence conifer forest is uncertain, the following guidelines should be followed (*from:* Naylor *et al.* 1996):

- encourage operators to leave unmerchantable portions of tree boles at harvest sites to provide large diameter DWD (bigger is better)

- where silvicultural objectives and health and safety concerns will not be compromised, consider girdling or felling and leaving unmerchantable stems

- where feasible, use site preparation equipment and techniques that do not windrow or crush DWD

- where feasible, use pre-harvest prescribed burns or burn when the water content of DWD is high.

SUPERCANOPY TREES

Supercanopy trees are large diameter trees (60+ cm DBH) that emerge above the main canopy of the stand. Scattered supercanopy trees are used by a select group of wildlife in the Great Lakes-St. Lawrence conifer forest. For example, black bears use large white pines and hemlocks as refuge trees and bedding sites (Rogers *et al.* 1988). Sows also commonly send their cubs up mature pines or hemlocks while they forage nearby (Rogers and Lindquist 1992). Supercanopy trees are used by large birds such as eagles, ospreys, turkey vultures, red-tailed hawks and common ravens as nest, roost, or perch sites (DeGraaf *et al.* 1992; Rogers and Lindquist 1992).

Current recommendations for the retention of supercanopy trees are based on the habitat needs of eagles, ospreys and black bears (Penak 1983; OMNR 1987b; Naylor 1994a) but should benefit other species as well. Eagle and osprey guidelines recommend the retention of supercanopy trees adjacent to nesting areas and within 400 m of occupied lakes (one supercanopy tree per 650 m of shoreline) to provide perch, roost and future nest sites (TABLE 8.3). In upland forest, Naylor (1994a) recommends the retention of at least one supercanopy tree per 4 ha to provide refuge trees and bedding sites for black bears.

8.1.3 Site Scale

Some relatively small scale habitats associated with specific geographic features (site-specific habitats) are disproportionately important habitat for wildlife and require special attention. For example, forest adjacent to lakes, rivers and streams (riparian habitat) influences water quality and fish habitat (***see*** references in OMNR 1988b) and may be used by about 40 per cent of the wildlife found in Great Lakes-St. Lawrence conifer forest (TABLE 8.1). Current guidelines affecting management within riparian areas focus on the protection of fish habitat and prescribe modification of activities within 30 to 90 m of the shoreline (OMNR 1988b). This helps protect habitat for wildlife species that nest in mature forest in riparian areas such as great-blue herons, eagles, merlins, wood ducks, common goldeneyes and hooded mergansers (Bellhouse and Naylor 1997).

However, natural disturbances such as blowdown and wildfire historically maintained some proportion of riparian areas in early successional forest. Some wildlife require this kind of habitat condition. For example, beavers forage in young riparian forest dominated by intolerant hardwoods and longevity of colonies is directly related to the amount of shoreline severely disturbed (Lewis *et al. in prep*.).

The fisheries guidelines (OMNR 1988b) permit some timber harvest within riparian areas surrounding warm water bodies and water courses. When consistent with objectives for recreation and aesthetics, this flexibility should be used to emulate natural landscape patterns and provide habitat for species such as beavers. Selection and shelterwood harvest will generally not create young riparian forest dominated by intolerant hardwoods or influence the longevity of beaver colonies (Lewis *et al. in prep*). Consequently, at least some of the area harvested within riparian zones should be clearcut. Clearcutting one entire shoreline (while leaving the opposite shoreline untouched) probably most closely mimics a natural pattern. If clearcuts are laid out as patches, they should be large enough to encourage regeneration of intolerant hardwoods (at least 40 m wide; OMNR 1986). Clearcuts should be conducted in those areas that are accessible to beavers (within 100 m of shoreline, low to moderate slope) and that currently contain some intolerant hardwoods (ES 18 to 21 probably have the greatest potential).

Small creeks, intermittent streams and seeps are other site-specific habitats of value to wildlife. For example, they provide critical habitat for northern two-lined salamanders and northern water shrews (DeGraaf and Rudis 1986; DeGraaf *et al.* 1992). These habitats are frequently not considered to be critical fish habitat and are thus not typically protected by the fisheries guidelines (OMNR 1988b). However, their integrity should be maintained by following the general philosophy prescribed by the *Code of Practice for Timber Management Operations in Riparian Areas* (OMNR 1991). Specifically:

- skid trails and landings should avoid seeps whenever possible
- movement of heavy equipment within creeks and associated riparian areas should be minimized
- tree tops should not be left in creeks
- a high canopy closure (70+ per cent) should be maintained when possible to maintain shading and cool water temperatures.

Skidder movement within these sensitive areas can be minimized by requiring operators to avoid seeps and cross creeks at a small number of designated points and by requiring them to winch trees out of the riparian areas (Naylor 1994a).

8.2 The Fine Filter

Correct application of the coarse filter approach should provide habitat for most wildlife species using the Great Lakes-St. Lawrence conifer forest. However, special consideration may be given to the needs of species that have specific habitat requirements that may not be explicitly or adequately addressed by the coarse filter approach. For example, retention of mature stands of conifer cover (coarse filter) only benefits deer if it is located in their yards and the cover is appropriately dispersed (fine filter) (***see*** Section 8.2.1 "White-tailed Deer"). In this situation, guidelines for individual species simply act to fine-tune the coarse filter. However, in some cases there may be compelling biological or socioeconomic reasons to manage the Great Lakes-St. Lawrence conifer forest to create more habitat for a species than the coarse filter approach would by itself (e.g. habitat supply adjusted to meet population targets based on societal demand). Finally, some species (especially those that are uncommon) that benefit from the general habitat conditions created by the coarse filter approach may still need protection for critical site-specific habitats such as nest sites (e.g. northern goshawk).

Habitat for these species may be considered at landscape, stand and/or site scales. At the landscape scale, the availability of habitat can be managed both spatially and temporally using a technique termed *habitat supply analysis* (HSA) (Naylor 1994b). In HSA, models of habitat suitability are applied to the forest inventory to produce estimates of current and future habitat supply. HSA can be used as both a strategic and tactical decision support tool. For example, the Strategic Forest Management Model can be used to evaluate the impact of general harvesting strategies (e.g. harvest level through time) on the long term supply of habitat. In a tactical role, HSA procedures can be used to address how operating blocks should be dispersed to meet shorter term, spatially explicit habitat supply objectives.

At the stand scale, silvicultural prescriptions can be modified to protect or enhance habitat suitability for individual species (e.g. maintain high canopy closure for winter shelter).

At the site scale, critical site-specific habitats (e.g. nest sites) can be protected through the area-of-concern (AOC) planning approach.

Management options are discussed below for species frequently considered to be of special concern within the Great Lakes-St. Lawrence forest.

8.2.1 White-tailed Deer

The white-tailed deer is a provincially featured species found throughout most of the Great Lakes-St. Lawrence forest. It has distinct seasonal home ranges and habitat requirements (Pruitt and Pruitt 1987). During summer, deer are dispersed across the landscape and feed on the growing tips, succulent shoots and flowers of shrubs, herbaceous plants and forbs (Voigt *et al.* 1997). Summer food supply influences growth rates and fecundity (Voigt *et al.* 1997). Food available in the spring and fall (cool-season forage and mast) is especially important as it helps deer recover from the stresses of the past winter and/or accumulate body fat in preparation for the coming winter. Summer carrying capacity (number of deer the summer range can support) is strongly influenced by the supply of early successional forest and non-forested habitats (e.g. developed agricultural land, meadows, old fields, clearings and wetlands) (Broadfoot *et al.* 1994; Bellhouse and Naylor 1997).

During winter, deer migrate to traditional use areas known as yards. Yards occupy about 10 per cent of the herd's summer range (Broadfoot *et al.* 1994). Deer feed on the twigs of a wide variety of hardwood and coniferous shrubs and saplings. Mature conifer cover is an essential habitat component (Verme 1965). Conifer cover ameliorates local climate thus reducing the energy deer expend to stay warm. Of greater importance, conifer cover also traps snow in its foliage. Much of this trapped snow sublimates, resulting in reduced snow depth under conifer cover and thus reduced energy expenditure by deer for movement (Pruitt and Pruitt 1987).

Management of deer habitat should begin with:

- an analysis of current carrying capacity of both summer (K_s) and winter range (K_w)

- an understanding of current population status and dynamics and population and habitat objectives

- an understanding of how application of the coarse filter guidelines may affect K_s and K_w

Estimates of current K_s and K_w can be derived using the habitat supply model developed by Broadfoot *et al.* (1994) and/or through analysis of field data on population and range condition (***see*** Voigt *et al.* 1997). The effects of application of the coarse filter guidelines on K_s and K_w can be predicted using Broadfoot *et al.*'s (1994) habitat supply model (e.g. Bellhouse and St. Martin

1996). From these analyses, habitat deficiencies on the entire summer and winter range can be identified. Tactics to improve K_s and K_w through management of the Great Lakes-St. Lawrence conifer forest on summer and winter range are discussed below.

If summer range is inadequate to meet objectives, carrying capacity can be increased by timber harvest and by sowing skid trails and log landings with cool-season forages such as clover, red fesque and birdsfoot trefoil (Voigt *et al.* 1997). Any cutting will increase the amount of summer food. However, clearcuts are the best way to produce good summer forage since many preferred foods are intolerant of shade. Clearcut (and shelterwood cut) sites will typically produce a high biomass of summer forage until tree saplings become well established (Broadfoot *et al.* 1994). Thus, clearcutting (or shelterwood cutting) should be scheduled to maintain a relatively continuous supply of early successional habitat across the summer range through time.

Clearcutting intended to create summer forage should focus on ecosites with a strong intolerant hardwood component (e.g. ES 18 and 19). These ecosites will produce the greatest amount of summer food (Broadfoot *et al.* 1994). Moreover, these sites can be managed on rotations that will maximize the area of early successional forest. Clearcuts in pine or hemlock-dominated forest will produce some summer food but should only be prescribed to improve deer range when objectives for summer range cannot be meet by clearcutting other ecosites and other objectives (timber, wildlife, recreation) will not be compromised.

The size and shape of clearcuts should be consistent with overall objectives for landscape diversity (***see*** “LANDSCAPE PATTERN” in Section 8.1.1 “Landscape Scale”). However, within these bounds, small patch clearcuts (up to 4 ha) or strip clearcuts (up to 100 m wide) are best for deer because they provide optimal interspersion of food and cover (Voigt *et al.* 1997). Clearcuts should avoid fragmenting large blocks of mature conifer forest if large blocks are a rare component of a forest landscape.

Voigt (1992a) emphasizes the special importance of mast-producing stands within 1 to 2 km of deer yards. Mast needs of deer on summer range should be satisfied when the general guidelines for mast production are followed (***see*** “MAST TREES” in Section 8.1.2 “Stand Scale”).

If winter range is inadequate to meet objectives, management should focus on the creation of browse and/or protection/enhancement of conifer cover. Habitat supply analysis should indicate which habitat component is most limiting.

Within deer yards, dense mature Great Lakes-St. Lawrence conifer stands dominated by hemlock (ES 30) or cedar (ES 21, 22, 33 and 34) can provide excellent winter cover and dense mature stands dominated by white pine, white spruce, or balsam (e.g. ES 11, 14, 18 and 20) can (depending on canopy closure) provide acceptable winter cover (Verme 1965; Euler and Thurston 1977; Broadfoot *et al.* 1994; Bellhouse and Naylor 1997). Timber harvest in these stands may be acceptable (and even beneficial) if it encourages development of browse and conifer regeneration. However, prescriptions for individual stands must consider the current and projected supply of winter cover in the yard (based on results of HSA). When individual mature stands are not required to meet current or short-term objectives for winter cover, stands can be managed using standard silvicultural practices to produce browse (***see*** below) or to ensure long-term supply of winter cover.

However, when the winter cover provided by individual stands is required to meet current or short-term cover objectives for the entire yard or a specific portion of the yard, the stands should either be deferred from harvest or should be harvested in a manner that will maintain or enhance shelter value. For example, winter cover can be maintained in hemlock stands if harvesting follows these guidelines (*modified from*: Voigt *et al.* 1997):

- harvest using group selection or shelterwood system

- focus on the removal of hardwoods except where removal may damage the residual conifer cover

- group selection and shelterwood seeding cuts should maintain at least 60 per cent conifer canopy closure in trees at least 10 m tall

- removal cuts in the shelterwood system should not be prescribed until conifer regeneration is at least 5 m tall and has at least 60 per cent canopy closure

- in bedding areas (e.g. knobs and ridges) and travel corridors, canopy closure should be maintained at 80 per cent

- maintain residual canopy in clumps of 3 to 5 trees with interlocking crowns where possible

- retain in order of cover value: hemlock, red spruce, cedar, white spruce, white pine and balsam.

The cover value of critical cedar stands can be maintained following the same guidelines. Krefting and Phillips (1970) found that deer use of selection and shelterwood cut cedar stands was at least as great as that of uncut forest. However, shelterwood cutting may be preferable to selection cutting. In cedar stands, the shelter provided by an uneven-aged stand structure is generally inferior to that provided by an even-aged structure (Verme 1965).

It is unlikely that the cover value of pine or spruce stands can be maintained when managed using standard silvicultural practices (uniform shelterwood or seedtree clearcut systems). Even shelterwood preparatory or seeding cuts produce a residual canopy cover that is generally too low to provide good winter cover (especially given the moderate snow interception capability of pine and spruce). Moreover, pine and spruce regeneration needs to be at least 10 m tall before it provides appreciable cover (Voigt *et al.* 1997). Thus, pine and spruce stands providing critical winter cover should generally be deferred from harvest.

While the above guidelines should protect winter cover in the short term, they are unlikely to successfully regenerate hemlock or cedar in the presence of high deer numbers. Regeneration of hemlock cover in the presence of high deer numbers may not be possible regardless of silvicultural system used (***see*** papers in Naylor and Thompson 1992). To maintain high quality cover in hemlock stands, managers may have to underplant a species such as red spruce. Red spruce is similar to hemlock in terms of shade tolerance, site requirements and snow interception capability but has low palatability to deer (Gordon 1992). Alternatively, managers may defer management of hemlock stands until deer numbers are low or deer distribution within a yard changes (Anderson 1992).

Clearcutting can be used to regenerate cedar in the presence of high deer numbers (Miller 1992). Verme (1965) recommends harvesting blocks of cedar using strip clearcuts. Uncut strips should be maintained on the site just long enough to ensure the establishment of cedar regeneration (if retained too long, deer will use the uncut strips to access and browse regenerating cedar in the cut strips; ***see*** Krefting and Phillips 1970). Cut blocks should be large (Verme suggests 16 to 65 ha) to discourage deer from browsing the cedar regeneration.

While dense mature Great Lakes-St. Lawrence conifer ecosites may provide winter cover, most generally have less than half the winter browse of hardwood-dominated stands or early successional forest (Broadfoot *et al.* 1994). When carrying capacity is limited by food (not cover) and is below expectations, food supply can be increased by timber harvest.

Clearcutting and shelterwood cutting of Great Lakes-St. Lawrence conifer forest will produce a high biomass of winter food until browse grows beyond the reach of deer (***see*** Broadfoot *et al.* 1994). Thus, cuts should be scheduled to create a relatively constant shifting mosaic of young forest across the yard through time.

The abundant browse produced by harvest will only benefit deer if they can access it. Only browse within 30 m of conifer cover is generally accessible when snow exceeds 50 cm in depth (Voigt *et al.* 1997; Broadfoot *et al.* 1994). Shelterwood preparatory and seeding cuts will generally maintain adequate cover to permit deer to access most of the browse on an operating block. Browse produced by clearcutting will be most accessible to deer when clearcutting is conducted in narrow strips or small patches. Strips should generally be < 100 m wide (Telfer 1978) and preferably 20 to 40 m wide (Rutske 1969; Krefting and Phillips 1970; Voigt *et al.* 1997). Small patch cuts are optimal when < 1 ha in size; Rutske (1969) recommended 40 m x 40 m patches in Minnesota and Smith and Borczon (1981) suggested 20 m x 80 m patches in Ontario. To maximize benefit to deer, uncut strips/patches should not be harvested until the cut strips/patches reach 5 to 10 m in height (Voigt *et al.* 1997).

Winter harvest is generally preferable since tops from recently cut trees provide an immediate food source (Voigt *et al.* 1997). However, this may not be desirable when site disturbance during the logging operation is needed to promote the establishment of tree species such as hemlock.

For more information on managing deer habitat ***see*** Voigt *et al*. (1997).

8.2.2 Moose

The moose is a provincially-featured species found throughout the northern portion of the Great Lakes-St. Lawrence forest. Like deer, moose have distinct seasonal habitat requirements, many of which, may be satisfied within the Great Lakes-St. Lawrence conifer forest. In summer, moose browse on the leaves of woody shrubs and saplings and forage on submerged and floating aquatic plants in wetlands or shallow bays of lakes (Jackson *et al.* 1991). Critical components of summer range include browse-producing habitat, aquatic feeding areas, mineral licks, calving sites and areas providing summer thermal shelter (Jackson *et al.* 1991). In early winter, moose forage on woody browse in areas of high browse production and some conifer cover. In late winter, moose make considerable use of dense mature stands of conifer (Allen *et al.* 1987; Jackson *et al.* 1991).

Management of moose habitat should begin with:

- an assessment of the supply of habitat using a habitat suitability model (e.g. Naylor *et al.* 1992)

- an understanding of population status and population and habitat targets

- an understanding of how habitat supply may be affected by application of the coarse filter guidelines**.**

Analysis of this information will help identify habitat deficiencies and help clarify what role stands within the Great Lakes-St. Lawrence conifer forest may play in meeting habitat objectives.

Areas of high summer and winter browse production are generally associated with shrubby habitats or young (early successional or recently cut) forest (Allen *et al.* 1987). Clearcut or shelterwood harvest within Great Lakes-St. Lawrence conifer forest creates habitat with an abundant supply of food (up to 10 times as much browse as in dense mature stands; Allen *et al.* 1987). Clearcutting may initially produce more browse than shelterwood cutting, but the latter may produce a relatively good supply of browse for a longer period of time (***see*** Kelty and Nyland 1983).

Recently disturbed forest will only produce an abundant supply of browse until shrubs/saplings grow beyond the reach of moose (< 20 years) (Allen *et al.* 1987; Lautenschlager 1993). Thus, scheduling of operating blocks should produce a shifting mosaic of young forest well-dispersed across moose range (***see*** Allen *et al.* 1987; Naylor *et al.* 1992).

Supply of browse in young forest can be influenced by chemical tending activities (***see*** review by Lautenschlager 1993). Untreated cuts may have substantially more browse in the first 10 years following harvest but treated cuts may have more browse 10 to 20 years after cutting (Lautenschlager 1993). Consequently, managers should model the impacts of herbicide treatments on browse supply across their management area through time and attempt to schedule treatments to meet browse supply objectives.

The size and shape of clearcuts and shelterwood cuts should be consistent with the coarse filter guidelines (***see*** "LANDSCAPE PATTERN" in Section 8.1.1 "Landscape Scale"). However, if the supply of browse is limiting moose density, use of cuts can be maximized (especially in early winter) by ensuring cut blocks are no more than 400 m wide (OMNR 1988a). (This is not necessarily inconsistent with the coarse filter guidelines since 75 per cent of blowdown patches in Wisconsin were < 400 m wide [Canham and Loucks 1984]). If cuts are wider, shelter patches, 3 to 5 ha in size and comprised of mature trees, should be retained within the cut block to ensure that moose using the cut block are never more than 200 m from cover.

During summer, moose bed in cool shady habitats to avoid heat stress (Jackson *et al.* 1991). Mature stands of lowland conifers (ES 31 to 34) are considered the best summer thermal shelter (Allen *et al.* 1987; Bellhouse and Naylor 1997). If there is less than 1 stand of lowland conifers or lowland hardwoods (ES 35) per km^2, summer thermal shelter may be limiting (***see*** Allen *et al.* 1987) and existing stands should be managed to maintain high canopy closure (80+ per cent).

Mature stands of Great Lakes-St. Lawrence conifer forest containing a significant mixture of intolerant hardwoods (ES 14, 18, 20 and 34) can be an important component of early winter habitat for moose (Bellhouse and Naylor 1997). These stands may receive high use because they tend to provide both abundant browse and winter shelter. Shelterwood timber harvest in these stands may increase browse supply while maintaining conifer cover. However, clearcutting will generally eliminate the cover they contain.

Dense mature stands in the Great Lakes-St. Lawrence conifer forest dominated by hemlock (ES 30), cedar (ES 22 and 33), white pine (ES 11), or mixtures of white pine with white spruce or cedar (ES 20 and 21) can be important late winter habitat for moose (Bellhouse and Naylor 1997). The supply of these stands should be managed to maintain a relatively constant, well-dispersed amount of late winter habitat across the management area through time (about 5 per cent of each township; ***see*** Naylor *et al.* 1992). Individual stands that are critical components of the current or short-term supply of late winter cover should either be deferred from harvest or managed following the guidelines described for maintaining winter cover for deer (***see*** Section 8.2.1 "White-tailed Deer").

Site-specific components of moose habitat may also be encountered in the Great Lakes-St. Lawrence conifer forest and should be managed through AOC planning. Stands of Great Lakes-St. Lawrence conifers may be located adjacent to moose aquatic feeding areas (MAFAs). When HSA suggests an abundance of MAFAs (more than 1.3 per cent of the landscape, well-distributed [***see*** Naylor *et al.* 1992]), not all MAFAs need to receive AOC designation (highest priority should be given to class 3 and 4 MAFAs). However, when HSA suggests a shortage of MAFAs, all MAFAs should be protected.

Current guidelines recommend a 120 m wide AOC around MAFAs (OMNR 1988a). In Great Lakes-St. Lawrence conifer forest, at least the first 30 m of this AOC should represent an uncut reserve to maintain dense overhead shade and thickets of shoreline conifers. This reserve provides hiding cover for moose calves (while cows are feeding in the MAFA) and cool bedding sites for adult moose. The width of the reserve will depend on the quality of the MAFA and the type of silviculture to be practiced inside and outside the AOC (TABLE 8.2). The remainder of the AOC could receive a selection or shelterwood harvest (although this should ideally be conducted outside the period of most intense use: June 1 to July 31). If small pockets of lowland conifers or lowland hardwoods are encountered in the AOC, a dense canopy closure should be maintained (80+ per cent) to provide summer thermal shelter.

Mineral licks are important components of moose range (Jackson *et al.* 1991) but are a rare feature in central Ontario. When they are identified, they should be treated as AOCs and protected with the MAFA guidelines.

Calving sites are also important components of summer range. Calving sites frequently occur on islands, peninsulas, or shorelines of lakes (Jackson *et al.* 1991) and will often either not be impacted by timber harvest or will be protected by riparian reserves. When calving sites are located within Great Lakes-St. Lawrence conifer forest subject to harvest they should be identified and receive a 120 m wide AOC (OMNR 1988a). The sites themselves should receive at least a 20 m reserve but the rest of the AOC could receive normal selection or shelterwood harvest (ideally conducted outside the calving period: May 1 to June 15). Wilton and Garner (1991) further suggest that within the AOC, slash should be lopped to a height of < 1 m to maintain visibility for cows.

For more information on managing moose habitat ***see*** OMNR (1988a) and Jackson *et al.* (1991).

TABLE 8.2: Width of reserve and modified management area (MMA) portions of areas-of-concern (AOCs) for moose aquatic feeding areas (MAFAs) based on MAFA class and type of harvest planned inside and outside the AOC.

MAFA CLASS	HARVEST INSIDE AOC	HARVEST OUTSIDE AOC	WIDTH[1] (m) OF RESERVE\MMA
2	Selection	Selection	30 / 90
		Shelterwood	30 / 90
		Clearcut	60 / 60
	Shelterwood	Selection	30 / 90
		Shelterwood	60 / 60
		Clearcut	90 / 30
3 or 4	Selection	Selection	30 / 90
		Shelterwood	60 / 60
		Clearcut	90 / 30
	Shelterwood	Selection	60 / 60
		Shelterwood	90 / 30
		Clearcut	120 / 0

[1] AOC measured from treed edge.

8.2.3 Pileated Woodpecker

The pileated woodpecker is a featured species found throughout the Great Lakes-St. Lawrence forest of central Ontario. Preferred nesting and feeding habitat is represented by some mature Great Lakes-St. Lawrence conifer forest types, especially those with a significant intolerant hardwood component (ES 11 to 14, 16, 18 to 22, 33 and 34; Bellhouse and Naylor 1997). Selection cuts and shelterwood preparatory or seeding cuts do not appear to significantly affect habitat suitability (Kirk and Naylor *in prep*.). However, clearcuts and shelterwood removal cuts produce habitat that will not be preferred again for nesting for 40 to 80 years.

Current guidelines (Naylor *et al.* 1996) require that strategic and tactical HSAs be conducted during forest management planning. Strategic analysis should ensure that proposed management activities will not result in a net loss of preferred nesting habitat relative to a landscape with a natural disturbance regime. Tactical analysis should ensure that preferred habitat occurs in patches that are of suitable size for pileated woodpeckers (***see*** Kirk and Naylor 1996; Naylor and Bush *in prep.*). Changes in the supply of preferred habitat within the Great Lakes-St. Lawrence conifer forest must be viewed within the context of changes in overall habitat supply, considering all forest types in the management area.

Cavity trees, snags and downed woody debris are important components of pileated woodpecker habitat, providing nest, roost and/or feeding sites (Kirk and Naylor 1996). These essential habitat features should be provided when the stand level coarse filter guidelines are applied (***see*** "CAVITY TREES" and "DOWNED WOODY DEBRIS" in Section 8.1.2 "Stand Scale").

For more information on managing habitat for pileated woodpeckers ***see*** Kirk and Naylor (1996) and Naylor *et al.* (1996).

8.2.4 American Marten

The American marten is a featured species within the boreal and northern (transition) portions of the Great Lakes-St. Lawrence forest. Mature Great Lakes-St. Lawrence conifer forest can be preferred habitat (ES 11, 14, 16, 18, 20 to 22, 30, 33 and 34; Bellhouse and Naylor 1997). Partial cuts that maintain at least 40 to 50 per cent canopy closure (e.g. selection and shelterwood preparatory or seeding cuts) will generally not affect habitat suitability (Watt *et al.* 1996). However, clearcuts and shelterwood removal cuts will generally create habitat that is unsuitable until the regenerating stand reaches the polewood stage.

Current guidelines for the provision of marten habitat (Watt *et al.* 1996) require strategic and tactical HSAs to be conducted during forest management planning. Strategic analysis should ensure that 10 to 20 per cent of the forest which is capable of providing marten habitat will be maintained in age classes that are suitable. Tactical analysis should ensure that suitable habitat is arranged in *core habitat areas* between 30 and 50 km^2 in size (with at least 75 per cent of this area in suitable habitat). Changes in the area of suitable Great Lakes-St. Lawrence conifer forest must be viewed within the context of changes in overall habitat supply, considering all forest types.

Cavity trees, snags and downed woody debris are important components of marten habitat, providing maternal den sites, winter rest sites, access to subnivean hunting habitat and/or cover for their major prey (Watt *et al.* 1996). These essential features of marten habitat should be provided when the stand level coarse filter guidelines are applied (***see*** "CAVITY TREES" and "DOWNED WOODY DEBRIS" in Section 8.1.2 "Stand Scale").

For more information on managing habitat for martens ***see*** Watt *et al.* (1996).

8.2.5 Eagles, Ospreys, Herons and Forest-nesting Raptors

Large stick nest builders such as bald eagles, ospreys, great blue herons, red-shouldered hawks, Cooper's hawks and northern goshawks are featured species within the Great Lakes-St. Lawrence forest. Eagles, ospreys and herons may nest in wetlands or riparian forest adjacent to Great Lakes-St. Lawrence conifer forest. One or more Great Lakes-St. Lawrence conifer ecosites represent nesting habitat for red-shouldered hawks, Cooper's hawks and goshawks (Bellhouse and Naylor 1997). When active nests of these species are located, they should be identified as AOCs and forest management activities should be modified based on the most current guidelines (TABLE 8.3).

Four other species of forest-nesting hawks and 3 species of owls use large platforms made of sticks for nesting. While these species are not generally considered to be of special concern, harvest activities should not be conducted within 150 m of active nests until the young have fledged (Naylor 1994a). Moreover, these nests may be used repeatedly and trees containing nests generally have a relatively unique branching architecture and represent rare and important structural components of wildlife habitat. Thus, trees containing stick nests used by these species should be retained in all selection and shelterwood preparatory or seeding cuts. To protect these trees from damage during harvest activities, trees with crowns touching the nest tree should also be retained (Naylor 1994a).

The peregrine falcon is considered an endangered species in Ontario and is thus provincially featured. It may nest on cliffs adjacent to Great Lakes-St. Lawrence conifer forest. Active eyries must be considered AOCs. Nest site management plans that identify acceptable levels of human disturbance (including forest management activities) within 3 km of the eyrie should be prepared (OMNR 1987a).

Application of AOC guidelines protects existing nest sites but does not ensure the maintenance of a supply of potential habitat across the broader forest landscape. HSAs can be conducted for individual species when there is concern that the coarse filter approach may not meet landscape level habitat objectives.

TABLE 8.3: Recommended guidelines for the protection of nesting habitat for raptors and great blue herons within the Great Lakes-St. Lawrence forest of central Ontario				
SPECIES	AREA OF CONCERN RESERVE / MMA[1]	PRESCRIPTION	TIMING RESTRICTION[7]	SOURCE
peregrine falcon (nests active within past 5 years)	3 km	• prepare nest site management plan documenting acceptable timing, amount and proximity of forest management activities	March 15 to August 31	OMNR1987a
bald eagle (nests active within past 5 years)	100 m reserve 100 m MMA1 200-600 m MMA2[2]	• selection harvest permitted in MMA1 • selection or shelterwood harvest permitted in MMA2 • retain at least 3 supercanopy trees within 400 m of nests to provide nest, roost and perch sites • within 400 m of eagle lakes, retain at least 1 supercanopy tree per 650 m of shoreline • protect nests not used within last 5 years with a 100 m reserve (no MMA) • avoid locating roads or landings in the AOC[6]	MMA1 Feb 15 to June 30 MMA2 Mar 15 to May 31	OMNR 1987b

TABLE 8.3: Recommended guidelines for the protection of nesting habitat for raptors and great blue herons within the Great Lakes-St. Lawrence forest of central Ontario

SPECIES	AREA OF CONCERN RESERVE / MMA[1]	PRESCRIPTION	TIMING RESTRICTION[7]	SOURCE
osprey (nests active within past 5 years)	150 m reserve 150 m MMA	• selection or shelterwood harvest permitted in MMA • retain at least 3 supercanopy trees within MMA to provide nest, roost and perch sites • within 400 m of osprey lakes, retain at least 1 supercanopy tree per 650 m of shoreline • protect nests not used within last 5 years with a 50 m reserve • avoid locating roads or landings in the AOC[6]	March 1 to July 31	Penak 1983 Naylor 1994a
great blue heron	150 m[3] reserve 150 m MMA	• selection or shelterwood harvest permitted in MMA • maintain minimum 30 m reserve where colony is > 150 m from treed edge • avoid locating roads or landings in the AOC	April 1 to August 15	Bowman & Siderius 1984 Agro & Naylor 1994

TABLE 8.3: Recommended guidelines for the protection of nesting habitat for raptors and great blue herons within the Great Lakes-St. Lawrence forest of central Ontario				
SPECIES	AREA OF CONCERN RESERVE / MMA[1]	PRESCRIPTION	TIMING RESTRICTION[7]	SOURCE
active red-shouldered hawk or Cooper's hawk	150 m reserve 150 m or 21 ha MMA	• selection harvest that retains at least 70 per cent canopy closure is permitted in the MMA • locate MMA so it encompasses suitable nesting habitat and satellite nests • protect satellite nests with a 20 m reserve • avoid locating roads or landings in the AOC[6]	March 1 to July 31	Szuba & Bell 1991
active northern goshawk[4]	50 m reserve 100 m MMA	• selection harvest that retains at least 70 per cent canopy closure is permitted in the MMA • protect satellite nests with no known history of use by a 20 m reserve • avoid locating roads or landings in the AOC[6]	March 1 to July 31	Naylor 1994a

TABLE 8.3: Recommended guidelines for the protection of nesting habitat for raptors and great blue herons within the Great Lakes-St. Lawrence forest of central Ontario

SPECIES	AREA OF CONCERN RESERVE / MMA[1]	PRESCRIPTION	TIMING RESTRICTION[7]	SOURCE
active broad-winged hawk, red-tailed hawk, sharp-shined hawk, or merlin	0 m reserve 150 m MMA	• selection, shelterwood, or clearcut harvest permitted within the MMA outside breeding season • hauling permitted through the MMA during breeding season if >50 m from active nest • in selection and shelterwood cuts, retain nest tree and adjacent trees to maintain high canopy closure and protect nest tree	March 1 to July 31	Naylor 1994a

TABLE 8.3: Recommended guidelines for the protection of nesting habitat for raptors and great blue herons within the Great Lakes-St. Lawrence forest of central Ontario

SPECIES	AREA OF CONCERN RESERVE / MMA[1]	PRESCRIPTION	TIMING RESTRICTION[7]	SOURCE
inactive[5] red-shouldered hawk, Cooper's hawk, or northern goshawk	20 m reserve	• confirm status before harvest		
inactive[5] broad-winged hawk, red-tailed hawk, sharp-shinned hawk, or merlin	no reserve	• in selection and shelterwood cuts, retain nest tree and adjacent trees to maintain high canopy closure and protect nest tree		

[1] Modified management area
[2] Based on topography and line of sight (***see*** OMNR 1987b: 13)
[3] Measured from edge of colony
[4] Apply guidelines to all nests in a cluster known to have been active within last 5 years
[5] Includes nests located outside breeding season when true identity and status of nest is unknown and those nests where species identity is known but which have not been used within the last 5 years
[6] Where roads must be located in the AOC, ensure the width of the cleared corridor does not exceed 10 m for tertiary roads and 20 m for secondary roads
[7] May be adjusted for local conditions and nest status (e.g. activity may be permitted in the MMA early if nest failed during incubation)

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9.0 Harvesting Considerations

9.0 Harvesting Considerations

by Harvey W. Anderson, Brian D. Batchelor, Carl M. Corbett and Bill Rose

9.1 Introduction

When harvesting under partial-cut systems like shelterwood and clearcut with seed trees, some degree of physical damage to residual stems and regeneration is inevitable. Damage to the site is also a concern in any silvicultural system when harvesting on some ecosites and/or under certain weather conditions. Minimizing the amount of damage by utililizing careful logging techniques is a critical factor in successfully achieving the forest management objectives.

Currently, most stands in the Great Lakes-St. Lawrence conifer forest are harvested using traditional "cut and skid" crews in which one or two cutters work with a skidder operator to harvest a block of timber. Mechanized logging, where a mechanical harvester works with a skidder, is becoming more common, particularly in northern Ontario. However, it only accounts for a small percentage of timber harvesting in the Great Lakes-St. Lawrence conifer forest.

This section covers the management implications of logging damage, the potential risk for damage by ecosite and some careful logging practices that can be utilized to minimize damage. The publication *Logging Damage: The Problems and Practical Solutions* (Rice 1994) has been cited extensively in this section. Although it deals primarily with tolerant hardwood management, it is a valuable reference for readers who seek more information on this subject.

Significant components of fish habitat including spawning sites, headwater areas, nursery areas and migration areas and overall water quality must be protected during all forest management activities in the conifer forest. This subject is not covered in this guide. Specific guidance is provided in *"Timber Management Guidelines for the Protection of Fish Habitat"* (OMNR 1988a), *"Environmental Guidelines for Access Roads and Water Crossings"* (OMNR 1988b) and *"Code of Practice for Timber Management Operations in Riparian Areas"* (OMNR 1991).

9.2 Management Implications

During harvesting operations in the Great Lakes-St. Lawrence conifer forest, the types of injury and damage that can potentially occur are:

- bole wounds caused by bark scraping or peeling
- root breakage
- branch breakage and resulting crown damage
- stem breakage/bending or tilting of trees from the upright position
- soil/site damage (e.g. erosion, rutting).

TABLE 9.0.1 identifies injury categories that are considered to be major. The type of injuries considered to be major have been derived from studies in tolerant hardwood trees as no information for the Great Lakes-St. Lawrence conifers could be found.

TABLE 9.0.1: Common injuries to trees during logging *(adapted from*: Nyland and Gabriel 1971)	
TYPE OF INJURY	CONSIDERED MAJOR WHEN...
Bark Scraped Off	Trees 10 - 31 cm DBH: Any wound greater than the square of the DBH (e.g. for a 10 cm DBH a major wound is greater than 100 cm^2
	Trees 32+ cm DBH: Any wound greater than 1,000 cm^2
	Note: If the wound has ground contact a major wound is considered to be 60 per cent of the size shown above for all size classes. For example, 60 cm^2 for a 10 cm DBH tree or 600 cm^2 for any tree 32+ cm DBH.
Broken Branches	More than 33% of the tree crown is destroyed
Root Damage	More than 25% of the root area is exposed or severed
Broken Off	Any tree
Bent Over	Any tree tipped noticeably

9.2.1 Bole Wounds Caused by Bark Scraping or Peeling

Bole wounds have serious management implications since they reduce the timber quality and volume of future harvests. In a study of improvement cutting in pine mixedwoods at the Petawawa National Forest Institute (PNFI), Brace (1978) reports that on average 30 per cent of all wound types had some decay associated with them after 5 years and this increased to 70 per cent (with advanced decay) for gouging-type (wood fibres broken) wounds. The study also determined that the size of wound had no impact on the incidence of infection *except* for felling scrapes on the butt log. For this type of wound infection incidence increased with wound size. Because the butt log is the most valuable log in the tree, this is of some concern.

Brace (1978) also reports that wood stain was associated with 63 per cent of all wounds and that the largest proportion of decay and stain was due to felling scrapes and skidding gouges, with the gouge-type injuries being the most serious.

The study concluded that 80 per cent of the residual stems were undamaged, 6 per cent were fatally damaged and 14 per cent sustained non-fatal wounds. The main point of concern is that 60 per cent of the non-fatal wounds were caused by skidding and the majority of those wounds consisted of the removal of bark from the lower 1 metre of the tree. Therefore, wounds are occurring on the valuable butt log, in many cases with ground contact, increasing the chance of decay and staining.

9.2.2 Root Breakage

Injuries occur to tree roots when:

- equipment or logs wound surface roots
- stems are jarred, severing some of the roots
- the ground around a tree is compacted
- skidder-caused ruts sever root systems (Dey 1994).

Damage to the root system can interfere with nutrient and moisture absorption, thereby reducing the vigour of the residual trees in a forest stand. If a large portion of the root system is sheared off by severe rutting, the residual stem will have reduced growth potential and be very susceptible to windthrow.

The most significant aspect of this damage is the creation of potential entry courts for infection by root-rot fungi. Whitney and Brace (1979) report that 50 per cent of the trees with "root spring" damage (a tree pushed 10 degrees or more from upright) were colonized by root destroying fungi. In addition to further weakening of the root systems, these fungi can also eventually extend into the merchantable portion of the tree.

9.2.3 Crown Damage Resulting from Branch Breakage

There are two primary management implications associated with branch / crown breakage. The first is the increased potential for wood stain or decay occurring. Brace (1978) reports that broken tops were the third most important cause of wood stain after felling scrapes and skidding gouges. The second concern regarding damage in the crown is due to the loss of photosynthesis potential and the subsequent reduction in tree vigour which can affect tree growth.

In the PNFI study, Whitney and Brace (1979) classified damage as 50 per cent or more of the crown being removed or if damage resulted in the removal of 2 or more years of terminal growth.

9.2.4 Stem Breakage and Bending or Tilting of Trees

Stem breakage/bending is a concern in all size-classes but has its greatest impact on the pole size class and on regeneration.

Nyland (1994) reports for hardwoods that the frequency of injuries to hardwoods of a given size class will likely be directly proportional to the numbers of trees in the class and that for stems less than 10 to 13 cm, the damage usually results in the destruction of the tree. In a seeding cut of shelterwood management, where much of the thinning is done from "below", protection of the pole size class from injury may not be of concern. However, in a pine-intolerant hardwood mixedwood stand in which the hardwood overstory is being removed to release the pine, protection of the polewood sized pine becomes critical to the future of the stand.

Damage of established regeneration is a concern in all harvest operations, particularly in shelterwood removal cuts. A study by the Algonquin Forestry Authority (Dunne and Corbett 1992) shows that adequate numbers of regeneration can survive a removal cut. In this study they assessed regeneration before and after a removal cut. Stocking to primary species (Pw, Pr) was 56.9 per cent (3,863 stems/ha) prior to harvest and 51.7 per cent (3,125) following harvest. Although approximately 20 per cent of the regeneration was lost in the harvesting operation, the stand is still considered to be adequately stocked to white and red pine since 40 per cent stocking is considered the minimum acceptable stocking.

This result mirrors, in some ways, the results of the pine mixedwood cut at PNFI where 20 per cent of the residual stems were damaged with 6 per cent of the residual stems being fatally damaged (Brace and Stewart 1974).

9.2.5 Soil and Site Damage

In addition to the impacts on the residual trees and regeneration there can also be considerable impacts to the site as the result of harvesting operations and/or site preparation activities. These operations can potentially cause compaction, rutting, erosion and nutrient loss. Factors influencing the potential for site damage include: the ecosite and associated soil types, environmental factors (season, precipitation), slope, the type of machinery being used and the skills and knowledge of the operator.

TABLES 9.0.2, 9.0.3 and 9.0.4 show the relative site damage hazard for compaction and rutting, erosion and nutrient loss respectively for the 27 soil types in the central Ontario FEC classification (Archibald *et al.* 1997). These tables are intended as a general guide to hazard potential. Soil/site conditions are rarely the same throughout a stand. Therefore the skill and knowledge of the harvesting crew and/or equipment operators during site preparation is always important in minimizing damage under any operating conditions.

9.2.5.1 Compaction

Compaction of the soil increases bulk density, reduces soil porosity, decreases infiltration rates and lowers soil permeability (Froehlich *et al.* 1981 *cited in* Dey [1994]). These changes in soil properties increase the potential for surface runoff and erosion and create less favourable soil environments for plant growth. Compaction can occur either during logging or site preparation when heavy equipment is operated when soils are moist or wet.

The following ecosite characteristics influence the potential risk for compaction:

- **Soil texture:** Coarse textured soils do not compact as easily as fine textured soils.

- **Per cent coarse fragments:** Soils with greater than 70 per cent coarse fragments have very low potential for compaction, regardless of soil texture.

- **Soil moisture:** Soils with a higher moisture regime are more prone to compaction.

Coarse sandy and fine sandy soil types have very little potential for compaction even when there is a low percentage of coarse fragments (Sutherland and Foreman 1995). Special care should be taken on fine textured soils that have < 30 per cent coarse fragments.

9.2.5.2 Rutting

The use of heavy machinery such as skidders may cause deep ruts (furrows or trenches) in the soil especially during extended periods of wet weather.

The impacts of ruts on a site as reported by Archibald *et al.* (1997) are as follows:

- ruts create an opportunity for water ponding which will reduce the productive area of the site

- ruts physically compact the soil on the sides and base of the rut which inhibits water infiltration, rooting and gas exchange

- ruts impede the lateral drainage of water on the site

- ruts contribute to erosion and soil displacement, especially on steep and/or longer slopes.

If rutting becomes severe enough, it can also lead to an increase in the incidence of stem wounding (bark abrasions and root severing) due to poor machine manoeuvrability and the subsequent establishment of new trails.

The following ecosite characteristics influence the potential risk for rutting:

- **Soil texture.** Coarse textured soils do not rut as easily as fine textured soils.

- Per cent **coarse fragments.** In general, soils with a high percentage of coarse fragments are less prone to rutting than soils relatively free of coarse fragments.

- **Depth and type of litter, slash and organic material.** Increasing amounts of these materials tend to reduce the potential for rutting by increasing the load-bearing capacity of the ground surface.

- **Soil moisture.** Soils with a higher moisture regime have a higher potential risk for rutting. All soils are more prone to rutting during the spring run-off or during extended periods of wet weather.

9.2.5.3 Erosion

Erosion is the accelerated movement of soil materials by the actions of water and/or wind.

As reported by Archibald *et al.* (1997 *in press*) soil erosion may impact a site by:

- reducing the productivity through the physical removal of the nutrient rich upper soil layers. In extreme cases this can result in some sites being unsuitable for timber production (e.g. exposed bedrock, steep gullies, sterile exposed mineral soil, smothering of productive soil profiles by sterile soils)

- degrading water quality and or fish habitat by depositing soil particles and nutrients into water bodies

- damaging or destroying residual trees.

The following ecosite characteristics influence the potential risk for erosion:

- **Topographic position.** The steeper and longer the slope the greater the potential for erosion.

- **The depth of litter and humus.** Exposed mineral soil is the most erodable substrate. Previous rutting of the soil and/or removal of the litter layer can increase the potential for erosion.

- **Permeability of the soil.** Compacted soils are less permeable and therefore will promote surface runoff on moderate slopes.

- **Soil depth.** Shallower soils have physically less water holding capacity and will therefore produce surface runoff more quickly than deeper soils.

TABLE 9.0.2: A general rutting and compaction hazard potential rating by soil type (Archibald *et al.* 1997 *in press*)									
RUTTING AND COMPACTION HAZARD FOR SOILS IN ONTARIO									
SOIL DESCRIPTION			FEC/ELC SOIL TYPE			SITE DAMAGE HAZARD			
texture	depth mineral	depth organic	Northwest	Northeast	Central	(soil moisture condition)			
						frozen	dry	moist	wet
mineral - all	0 - 5	0 - 20	SS1,SS2,SS4	SS1,SS2,SS4	SS1,SS2,SS4,(s17)	L	L	M	H
mineral - all	6 - 30	0 - 20	SS3,SS4,(ss5-ss8)	SS3,SS4	SS3,SS4	L	L	M	H
sandy	31 - 60	0 - 20	SS5,(ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	L	L	L	M
sandy	61+	0 - 20	S1,S2, S7,(ss5,ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	L	L	L	M
coarse loamy	31 - 60	0 - 20	SS6,(ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	L	M	H
coarse loamy	61+	0 - 20	S3,S8(ss6,ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	L	M	H
silty	31 - 60	0 - 20	SS7,(ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	L	M	H
silty	61+	0 - 20	S4,S9(ss7,ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	L	M	H
f. loamy - clayey	31 - 60	0 - 20	SS7,(ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	L	M	H
f. loamy - clayey	61+	0 - 20	S5,S6,S10,(ss7,ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	L	M	H
organic - fibric	all	21 - 40	SS9,S11	S16	SS5,S18	L	M	H	H
org - mesic/humic	all	21 - 40	SS9,S11	S16	SS5,S18	L	H	H	H
organic - fibric	all	41+	SS9,S12F,S12S	S17	S19	L	M	H	H
org - mesic/humic	all	41+	SS9,S12F,S12S	S18,S19	S20,S21	L	M	H	H

L = low, M = medium, H = high

TABLE 9.0.3: A general erosion hazard potential rating by soil type (Archibald *et al.* 1997 *in press*)								
EROSION HAZARD FOR SOILS IN ONTARIO								
SOIL DESCRIPTION			FEC/ELC SOIL TYPE			SITE DAMAGE HAZARD		
texture	depth mineral	depth organic	Northwest	Northeast	Central	slope 0 - 10%	11 - 30%	>30%
mineral - all	0 - 5	0 - 20	SS1,SS2,SS4	SS1,SS2,SS4	SS1,SS2,SS4,(s17)	M	H	H
mineral - all	6 - 30	0 - 20	SS3,SS4,(ss5-ss8)	SS3,SS4	SS3,SS4	L	M	H
sandy	31 - 60	0 - 20	SS5,(ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	L	M/H	H
sandy	61+	0 - 20	S1,S2, S7,(ss5,ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	L	M/H	H
coarse loamy	31 - 60	0 - 20	SS6,(ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	M	H
coarse loamy	61+	0 - 20	S3,S8(ss6,ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	M	H
silty	31 - 60	0 - 20	SS7,(ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	M/H	H
silty	61+	0 - 20	S4,S9(ss7,ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	M/H	H
f. loamy - clayey	31 - 60	0 - 20	SS7,(ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	M	H
f. loamy - clayey	61+	0 - 20	S5,S6,S10,(ss7,ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	M	H
organic - fibric	all	21 - 40	SS9,S11	S16	SS5,S18	L	L	
org - mesic/humic	all	21 - 40	SS9,S11	S16	SS5,S18	L	M	
organic - fibric	all	41+	SS9,S12F,S12S	S17	S19	L		
org - mesic/humic	all	41+	SS9,S12F,S12S	S18,S19	S20,S21	L		

L = low, M = medium, H = high

9.2.5.4 Nutrient loss

The amount of nutrients contained in harvested timber varies with species, age, soil conditions and the intensity of the harvest. There is no evidence to indicate that conventional practices, particularly the shelterwood system, result in a significant direct loss of nutrients that will affect forest productivity (Clements 1973).

The forest floor is important for the biochemistry and ecology of a conifer forest, especially on acid substrates with a low mineral-nutrient supply. A high proportion of the available nutrients on such sites is localized in the organic matter of the forest floor, which tends to be maintained by litterfall (Bormann and Likens 1979; Heij and Leek 1981). Therefore, prompt re-vegetation of cutover stands will minimize nutrient loss (Hendrickson *et al.* 1982).

As reported by Archibald *et al.* (1997 *in press*) the sites where there is a higher potential for nutrient loss are those with the least nutrient capital stored including:

- coarse textured sands
- soils with little or no accumulated organic matter and/or little organic incorporation in the mineral soil profile
- very shallow soils, especially where the organic mat may be lost or damaged after harvesting or site preparation
- pure conifer stands on nutrient poor sites.

TABLE 9.0.4: A general nutrient loss hazard potential rating by soil type (Archibald *et al.* 1997 *in press*)								
NUTRIENT LOSS HAZARD FOR SOILS IN ONTARIO								
SOIL DESCRIPTION			FEC/ELC SOIL TYPE			SITE DAMAGE HAZARD		
texture	depth mineral	depth organic	Northwest	Northeast	Central	Clearcut Full Tree	Clearcut Not Full Tree	Selection Shelter-wood
mineral - all	0 - 5	0 - 5	SS1,SS2,SS4	SS1,SS2,SS4	SS1,SS2,SS4,(s17)	H	H	M
mineral - all	0 - 5	6 - 20	SS1,SS2,SS4	SS1,SS2,SS4	SS1,SS2,SS4,(s17)	H	H	M
mineral - all	6 - 30	0 - 5	SS3,SS4, (ss5-ss8)	SS3,SS4	SS3,SS4	H	H	L
mineral - all	6 - 30	6 - 20	SS3,SS4, (ss5-ss8)	SS3,SS4	SS3,SS4	H	M	L
sandy	31 - 60	0 - 5	SS5,(ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	H/M	M/L	L
sandy	31 - 60	6 - 20	SS5,(ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	M	L	L
sandy	61+	0 - 5	S1,S2,S7,(ss5,ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	M	L	L
sandy	61+	6 - 20	S1,S2,S7,(ss5,ss8)	S1,S2,S3,S4,(s15)	S1,S2,S5,S6,S9,S10,S13,S14	L	L	L
coarse loamy	31 - 60	0 - 20	SS6,(ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	L	L
coarse loamy	61+	0 - 20	S3,S8,(ss6,ss8)	S5,S6,S7,S8,(s15)	S3,S7,S11,S15	L	L	L
silty	31 - 60	0 - 20	SS7,(ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	L	L
silty	61+	0 - 20	S4,S9,(ss7,ss8)	S9,S10,S11,S12,(s15)	S3,S7,S11,S15	L	L	L
f. loamy - clayey	31 - 60	0 - 20	SS7,(ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	L	L
f. loamy - clayey	61+	0 - 20	S5,S6,S10,(ss7,ss8)	S13,S14,(s15)	S4,S8,S12,S16	L	L	L
organic - fibric	all	21 - 40	SS9,S11	S16	SS5,S18	M/L	L	L
org - mesic/humic	all	21 - 40	SS9,S11	S16	SS5,S18	M/L	L	L
organic - fibric	all	41+	SS9,S12F,S12S	S17	S19	M/L	L	L
org - mesic/humic	all	41+	SS9,S12F,S12S	S18,S19	S20,S21	M/L	L	L

L = low, M = medium, H = high

9.3 Careful Logging Practices

Careful logging is the harvesting of timber products in a manner that avoids any injury to forest workers while minimizing damage to residual trees, regeneration and the site.

The key elements in achieving this are:

- appropriate planning at all stages of the harvesting operation
- the training, experience and silvicultural knowledge of the workers involved in the harvesting
- clear objectives relating to stand health that the harvesting crew and forest manager can co-operatively achieve.

Planning is an extremely important and effective tool for minimizing logging damage. Many problems can be minimized or avoided altogether with appropriate planning from the Forest Management Plan down to operational planning on an individual cut block.

The Forest Management Plan should stress the importance of minimizing damage to residual trees and regeneration and should also identify those stands on ecosites which may be more susceptible to site damage at certain times of the year.

This type of identification allows those preparing the Annual Work Schedule (AWS) to schedule operations to either avoid harvesting sites at times that there is a high potential for excessive logging damage, or to be ready for potential problems under certain weather conditions.

For example, some jurisdictions plan their harvest so that crews are not working in tolerant hardwood stands in the spring when the hardwoods are most susceptible to bark damage. This also avoids having the harvesting operations take place on these sites if wet spring soil conditions exist.

Another alternative is to establish clear objectives and standards that would apply regardless of time of year and/or soil conditions. Logging practices may then have to be modified or cease under certain operating conditions, in order to meet the desired objectives.

In either instance, this type of planning requires that forest managers have a good understanding of the stands and site conditions in their area. It also requires good communication with the forest industry so that problems with wood supply to the mills can also be dealt with early in the planning process. If the mill requires a certain product mix, this has to be known and operations scheduled to avoid delivery problems while also minimizing logging damage problems in the field.

Planning at the individual cut block is also extremely important. The harvesting crew should know the terrain, site conditions and silvicultural objectives of the cut block. This allows them to plan the harvesting to ensure a safe and effective cut progression to optimize their production and to minimize logging damage.

It is at this stage that the training, experience and silvicultural knowledge of the harvesting crew is important. Safe and effective cut progression is dependant upon operators with a good knowledge of safe and proper felling and skidding techniques as well as an understanding of the silvicultural system (and the operating concerns) they are harvesting under.

Utilizing appropriate felling techniques to control the direction of fall of each tree is necessary to effectively work in partial cutting systems such as selection and shelterwood. Directional felling is not only the safest way to harvest but also reduces operating costs and logging damage by:

- Limiting the number of "hung up" trees. These often require skidder assistance to get them down safely, increasing operating costs. Hung up trees cost the operator time and money while extra travel by the skidder increases the potential for logging damage.

- Reducing the amount of turning necessary to get a log aligned for the direction of skidding. Turning the log requires time and also increases the potential for logging damage.

- Where damage to either residuals or regeneration is unavoidable, directional felling techniques enable the worker to choose where the damage will occur. This could mean damaging a stem marked for removal or a residual "unacceptable growing stock" (UGS) stem instead of an "acceptable growing stock" (AGS) stem or desirable regeneration.

The training and knowledge of the skidder operator is also an important element in reducing logging damage. Nyland (1994) reports that basal wounds occur on 70 per cent of trail-side trees so it is extremely important that the number of skid trails be minimized and controlled. This is best accomplished by operators that know their block and plan the harvest and skid-trails appropriately.

Some examples of careful logging skidding techniques include:

- avoiding wet and/or poorly drained areas as much as possible

- using straight or gently curving skid trails

- leaving "bumper trees" at key points to absorb damage. These "bumper trees" should ideally be ones that have been marked for removal or that are unacceptable growing stock (UGS)

- using the main-line and winch to reduce the amount of travel necessary by the skidder.

Another important factor is communication between a forest manager and the harvesting crew. Nyland (1994) felt that the key element in conducting a successful harvesting operation was developing a rapport with the harvesting contractor. If an operator understands what the forest manager is trying to accomplish in managing the stand, the operator will take the necessary steps to minimize logging damage. The attitude and skill of a logging crew is probably the most important factor in minimizing logging damage.

The Algonquin Forest Authority came to a similar conclusion following the study, mentioned earlier, of a shelterwood removal cut in the fall of 1991. One of the major findings of this study was that the forest managers should utilize the experience of the cut and skid crews in trail layout to help reduce damage.

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10.0 Management Standards

10.0 Management Standards

by Fred N.L. Pinto, Dan Galley, Al S. Corlett, Brian D. Batchelor, Steve Munro, Andrée E. Morneault, Jeff Leavey and Brian J. Naylor

Many forest- and stand-level objectives are accomplished through silvicultural activities. These objectives are identified in the Forest Management Plan and linked to specific measurable standards in the silvicultural ground rules (***see*** Section 7.1.1 "Silvicultural Ground Rules" and TABLE FMP-10 in OMNR [1996]). These standards should reflect areas of critical concern such as forest health and long-term product goals. Useful indices to develop standards in a Forest Management Plan are:

- measures of species composition
- stocking, density
- quality of the growing stock
- stand and forest structure
- physical impacts of management activities on the site.

While suggested standards are defined below, it is expected that some variation from the standards or guidelines presented may be necessary at the local forest level. Ecological rationale for such adjustments must be provided in the Forest Management Plan. These changes will not be considered exceptions to the standards or guidelines provided they are based upon documented past experience or scientific literature. Most importantly, the regeneration standards in a Forest Management Plan must reflect the regeneration success assumptions used in the calculation of allowable harvest levels.

The following principles have been used in the development of suggested standards and should be considered in any locally required modifications:

- Standards related to target species and species association selection, residual overstory and regeneration stocking levels, logging damage, etc., must be:
    - ecologically suited to the site
    - at levels that ensure attainment of long-term resource objectives for the site.
- Standards must recognize that the maintenance of ecological sustainablity is paramount; silvicultural treatments will be modified and modifications must be practical and measurable.

10.1 Standards Required for the Application of Silviculture Systems

Specifications for intensity of disturbance, (i.e. type of disturbance, size of stand opening and frequency of disturbance) vary with the stand objective. For example, the need to maintain visual quality and white pine in a stand may result in the use of the uniform shelterwood system. The regeneration and growth adaptations of white pine must be considered in the choice of the type of disturbance, size of openings in the stand and in the timing of disturbances. These limits are described in Section 7.2 “Silvicultural Systems” for each of the species in the Great Lakes-St. Lawrence conifer forest.

The proper application of partial cutting systems results in changes to stand quality and stand structure. Improperly applied, these systems will result in the high-grading of stands and over time, the high-grading of the forest.

Tree marking is the mechanism by which silvicultural systems involving partial cutting are implemented. Proper tree marking ensures consistent delivery of policies related to silviculture, stand regulation, habitat manipulation and other forest values. It is through the tree-marking process that the critical decisions regarding vigour and risk of residuals and consideration of phenotypic qualities of the seed producers are made. Following the harvest, standard achievement cannot be examined since the options available to the marker are no longer apparent.

The proper use of the uniform shelterwood system in Great Lakes-St. Lawrence conifer forest will result in an increase in average diameter of forest stands after the preparatory and regeneration cuts. Applied improperly, average stand diameter will be lower after the harvest. Increase in average diameter occurs because the stand is thinned from below (i.e. smaller trees are removed and dominant and codominant trees are retained for continued growth) and as a source of seed for regeneration.

Use of the selection and shelterwood silvicultural systems require rules that govern the removal and retention of trees. The following factors must be considered in determining the removal or retention of trees:

- Vigour and risk characteristics of residuals, trees selected for removal are those judged unlikely to survive until the next harvest.

- Residual stocking levels which optimize both volume production and the development of regeneration, (***see*** Section 5.0 “Stand Growth and Yield” and Section 7.2 “Silvicultural Systems” for appropriate levels).

- The level of stem or root damage incurred by the residuals during the process of harvest or follow-up silvicultural treatment (***see*** Section 9.0 “Harvesting Considerations”).

- Residual species composition and retention status for tree species vary by stand objective (which is set within the context of the forest-level biodiversity objective) and the silvics of the tree species found on each ecosite. ***See*** TABLE 10.0.1 for suggestions.

TABLE 10.0.1 Examples of acceptable overstory species for retention and targets for stocking of regeneration on Great Lakes-St. Lawrence conifer forest ecosites							
FOREST UNIT	CENTRAL ONTARIO ECOSITE	RESIDUAL OVERSTORY	REGENERATION				
(FU)	(ES)	Preferred Species	Acceptable Species Listed in Priority	Minimum Stocking Per cent All Species (FU)	Density Number of Stems/ha	Total Height Minimum (m)	Assessment Timing Years After Treatment*
Pw	20.1, 20.2	Pw, Pr, Sw	Pw, Pr, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	13.1, 13.2 11.1, 11.2	Pw, Pr, Sw, Pj	Pw, Pr, Sw, Pj	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	21.1, 21.2	Sr, Pw, Sw, Ce	Sr, Pw, Sw, Ce	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	14.1 14.2	Pw, Or, Pr, He Pw, Or, Sw	Pw, Or, Pr, He Pw, Or, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	12.1 12.2	Pw, Pr Pw, Pr, Sw	Pw, Pr Pw, Pr, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	16.1	Pw, Pr, Pj, Sb, Ce	Pw, Pr, Pj, Sb	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
Pr	20.1, 20.2	Pr, Pw, Sw	Pr, Pw, Sw	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7
	11.1	Pr, Po, Or, Sw	Pr, Po, Or, Sw	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7
	11.2	Pr, Pw, Sw	Pr, Pw, Sw	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7
	12.1, 12.2	Pr, Pw, Sw	Pr, Pw, Sw	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7
		Pr, Pw, Sw, Or, Sb, Pj	Pr, Pw, Sw, Or, Sb, Pj	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7

* Nat - natural regeneration; Art - artificial regeneration

Note: Stocking based upon 2 m x 2 m plots

TABLE 10.0.1 Examples of acceptable overstory species for retention and targets for stocking of regeneration on Great Lakes-St. Lawrence conifer forest ecosites							
FOREST UNIT	CENTRAL ONTARIO ECOSITE	RESIDUAL OVERSTORY	REGENERATION				
(FU)	(ES)	Preferred Species	Acceptable Species Listed in Priority	Minimum Stocking Per cent All Species (FU)	Density Number of Stems/ha	Total Height Minimum (m)	Assessment Timing Years After Treatment*
Sw	18.1, 18.2	Sw, Pw	Sw, Pw	40	1000	1	Nat 7-10 Art 5-7
	19.1, 19.2	Sw, Sb, Pj	Sw, Sb, Pj	40	1000	1	Nat 7-10 Art 5-7
	20.1	Sw, Pw, Pr, Sb	Sw, Pw, Pr, Sb	40	1000	1	Nat 7-10 Art 5-7
	20.2	Sw, Pw, Pr	Sw, Pw, Pr	40	1000	1	Nat 7-10 Art 5-7
	22	Sw, Pw, By, Sb, Ce	Sw,Sr,Sb, Pw, By, , Ce	40	1000	1	Nat 7-10 Art 5-7
	33	Sw, By, Sb, Ce	Sw, Sb, Sr, Ce	40	1000	1	Nat 7-10 Art 5-7
Ce	21.1	Sr, Ce, Pw, Sw	Sr, Ce, Pw, Sw	40 Ce 30	1000 750	1	Nat 7-10 Art 5-7
	21.2	Sr, Ce, Pw, Sw, By	Sr, Ce, Pw, Sw, By	40 Ce 30	1000 750	1	Nat 7-10 Art 5-7
	32	Sr, Ce, Sb, La	Sr, Ce, Sb, La	40 Ce 30	1000 750	1	Nat 7-10 Art 5-7
	22	Ce, Sw, Pw, By	Ce, Sw, Pw, By	40 Ce 30	1000 750	1	Nat 7-10 Art 5-7
	33	Ce, Sb, By, Sw, Ab	Ce, Sb, By, Sw, Ab	40 Ce 30	1000 750	1	Nat 7-10 Art 5-7

* Nat - natural regeneration; Art - artificial regeneration

Note: Stocking based upon 2 m x 2 m plots

TABLE 10.0.1 Examples of acceptable overstory species for retention and targets for stocking of regeneration on Great Lakes-St. Lawrence conifer forest ecosites							
FOREST UNIT	CENTRAL ONTARIO ECOSITE	RESIDUAL OVERSTORY	REGENERATION				
(FU)	(ES)	Preferred Species	Acceptable Species Listed in Priority	Minimum Stocking Per cent All Species (FU)	Density Number of Stems/ha	Total Height Minimum (m)	Assessment Timing Years After Treatment*
He	30.1, 30.2	He, By, Pw	He, By, Pw, Sw, Sr	40 He 30	1000 750	1	Nat 7-10 Art 5-7
Sr	21.1	Sr, Pw, Sw, Ce	Sr, Pw, Sw, Ce	40	1000 750	1	Nat 7-10 Art 5-7
	21.2	Sr, Pw, Sw, Ce, By	Sr, Pw, Sw, Ce, By	40	1000 750	1	Nat 7-10 Art 5-7
	32	Sr, Ce, Sb	Sr, Ce, Sb	40	1000 750	1	Nat 7-10 Art 5-7
Pj	19.1, 19.2	Pj, Sw, Sb	Pj, Sw, Sb	40 Pj 30	1000 750	1	Nat 7-10 Art 5-7
	13.1, 13.2	Pj, Pw, Pr	Pj, Pw, Pr	40 Pj 30	1000 750	1	Nat 7-10 Art 5-7
Or	14.1	Or, Pw, Pr, He	Or, Pw, Pr, He	40 Or 30	1000 750	1	Nat 7-10 Art 5-7
	14.2	Or, Pw, Pr	Or, Pw, Pr	40 Or 30	1000 750	1	Nat 7-10 Art 5-7

* Nat - natural regeneration; Art - artificial regeneration

Note: Stocking based upon 2 m x 2 m plots

TABLE 10.0.1 Examples of acceptable overstory species for retention and targets for stocking of regeneration on Great Lakes-St. Lawrence conifer forest ecosites							
FOREST UNIT	CENTRAL ONTARIO ECOSITE	RESIDUAL OVERSTORY	REGENERATION				
(FU)	(ES)	Preferred Species	Acceptable Species Listed in Priority	Minimum Stocking Per cent All Species (FU)	Density Number of Stems/ha	Total Height Minimum (m)	Assessment Timing Years After Treatment*
Convert to Pw	30.1	Pw, He, By	Pw, He, By, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	18.1, 18.2	Pw, Sw	Pw, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	19.1, 19.2	Sw, Sb, Pj	Pw, Sw, Sb, Pj	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
	17.1	Pw, Po, Bw	Pw, Pr, Sw	40 Pw 30	1000 750	1	Nat 7-10 Art 5-7
Convert to Pr	17.1	Pr, Po, Bw	Pr, Po, Bw	40 Pr 30	1000 750	1	Nat 7-10 Art 5-7
Convert to Sw	17.2	Sw, Pw, Po	Sw, Pw	40	1000	1	Nat 7-10 Art 5-7
Convert to Pj	18.1	Pj, Sw, Pw	Pj, Sw, Pw, Pr	40 Pj 30	1000 750	1	Nat 7-10 Art 5-7

* Nat - natural regeneration; Art - artificial regeneration

Note: Stocking based upon 2 m x 2 m plots

10.2 Determining Free-to-Grow Standards

Stands that are free-to-grow are "stands that meet stocking, height and/or height growth rate, as defined by the specifications or standards, and are judged to be essentially free from competing vegetation" (Canadian Forestry Service 1988). Being "free of competing vegetation" implies that the desired tree species is capable of achieving minimum survival and/or growth objectives as defined in the management plan.

Many studies have indicated that stem diameter and biomass growth are more sensitive to different levels of competing vegetation than height growth (OMNR 1993). Height growth is among the highest priorities for resource allocation in young trees and therefore is the least sensitive growth variable to high levels of competing vegetation (ONMR 1993). When height growth is reduced, survival is threatened. Therefore, competing vegetation standards for survival are closely linked to those for height growth. Acceptable levels of competing vegetation are different when the objective is to maintain or achieve a minimum level of stem diameter or biomass growth.

If the management objective is to *achieve or maintain height growth and/or survival of desired tree species,* free of competing vegetation means that the desired crop trees should not be overtopped by non-crop woody vegetation. Height growth and survival of young trees are threatened when woody plants are either taller than the tree or, based on the projected height growth of the woody plants and the desired tree, will be taller than the tree within the next three years (OMNR 1993). A plantation may require vegetation management treatments when more than 10 per cent of the desired crop tree stocking is overtopped by woody non-crop tree vegetation (OMNR 1993).

If the management objective is to *achieve or maintain diameter or biomass growth of the desired tree species,* desired crop trees should not be surrounded by non-crop woody vegetation that exceed half of the desired tree height, or, based on the projected height growth of the woody plants and the desired tree, the woody vegetation should not exceed half tree height within the next three years (OMNR 1993). A plantation may require vegetation management treatments when more than 20 per cent of desired crop tree stocking is surrounded by non-crop woody vegetation at least half of the desired tree height.

Herbaceous vegetation can also substantially reduce tree growth and survival. The levels of herbaceous vegetation that can cause reductions in growth or survival will depend on crop tree species and ecosite. The information required to make recommendations is currently lacking in the literature.

10.3 Maintenance of Biodiversity

Effects of cumulative stand silvicultural activities will affect forest biodiversity and thus affect forest sustainability. To ensure forest sustainability, the forest manager must have standards that can be used to define and guide the planning and implementation of silvicultural activities.

Forest managers must be aware of the consequences of silvicultural practices on:

- genetic diversity
- stand species composition
- stand structure: physical structure and stand age-class.

One important approach to maintaining genetic diversity is through selection of trees for retention in partial cuts and the choice of tree species for renewal. Recommended tree species retention and renewal choices for each ecosite and stand species objective are described in TABLE 10.0.1.

Other practices and standards for maintenance and restoration of diversity are described in Section 7.2.4 “Modifications to Conventional Silvicultural Systems”.

Minimum stocking and density levels are described in Table 10.0.1. They will be used, as a starting point, in the preparation of regeneration standards in silvicultural ground rules. The regeneration standards in a Forest Management Plan will be used to determine renewal success or failure.

Stand structural diversity is important for ecosystem function. For example, cavity trees serve as roosting, breeding and feeding sites for a large number of vertebrate species. Structural diversity standards may be found in Section 8.0 “Integrating Timber and Wildlife Habitat Considerations” and Section 7.2.4 “Modifications to Conventional Silvicultural Systems”.

The age-class of a forest is affected by harvest and renewal activities. Decisions on stand harvest and renewal must consider the age-class that natural disturbances would create. Computer models such as LEAP II and SFMM may be used for this exercise during the preparation of a Forest Management Plan. Harvest and renewal activities should then attempt to emulate, to the extent possible, the hypothetical natural age-class for the forest. Methods and standards on how to model the hypothetical natural age-class of a forest can be found in Section 8.0 “Integrating Timber and Wildlife Habitat Considerations”.

10.4 Maintenance of Productivity

Stand productivity can be maintained by application of the correct silvicultural treatment. Site visits prior to operations will minimize the possibility of operations detrimental to productivity from occurring. ***See*** Section 7.1 “Prescription Development” for suggestions and standards for the development of site specific prescriptions.

Standards of site productivity may be developed using information found in Section 5.0 “Stand Growth and Yield”. These standards, usually growth curves, for a particular silvicultural treatment package in the silvicultural ground rules of a Forest Management Plan, provide an opportunity to monitor the new forest stand and determine how closely stand productivity objectives are being met.

Some silvicultural treatments will result in stand and site damage, such as soil compaction. These types of damage to the productive potential of the stand can be minimized if the methods described in Section 9.0 “Harvesting Considerations” are adhered to.

TABLE 10.0.2 shows stand-level standards for partial-cut systems that are recommended to limit stand and site damage. They are known to be operationally attainable. They are based on the experience of practitioners and also research into logging and site damage.

Standards related to site compaction or rutting should be developed at the management unit level. Variation in significance of rutting potential is related to ecosite, soil textural class and seasonal rainfall levels. Those factors are explained in Section 9.0 “Harvesting Considerations” and Section 7.3 “Site Preparation”. TABLE 10.0.3 illustrates local guidelines developed by the Algonquin Forestry Authority in conjunction with area operators. It must be noted that these guidelines are a first attempt and future modifications are anticipated. They are included here as an example only and should not be construed as having relevance outside of the area for which they were designed.

TABLE 10.0.2: Stand-level standards for stand and site damage in partial-cut systems	
DAMAGE TYPE	STANDARD
Damage to residual stems	After harvesting, 85% of the residual basal area (10 cm +) should be free of major damage and 90% of the residual AGS should be free of major damage. Incidence of damage should not be concentrated in any one size class.
Damage to regeneration	Minimum stocking standards as detailed in the "free-to-grow" standards must be maintained following release operations (i.e. removal cuts of the shelterwood system).
Skid trail coverage	A minimum of 70% of the ground area in uniform shelterwood areas and 80% in selection areas is to be skid-trail free.

TABLE 10.0.3: Local guidelines to protect against site damage developed by the Algonquin Forestry Authority			
SKID TRAIL CATEGORY	MAXIMUM DISTANCE OF COMPACTION PER SKID TRAIL	MAXIMUM DISTANCE OF COMPACTION PER LANDING	OPERATIONAL STATUS
Minor - 15 cm or less compaction	Can be maintained over the length of the trail	Can be maintained over entire system of main skid trails	None
Moderate - 16 cm to 30 cm of compaction	Can be maintained over the length of the trail	Can be maintained over entire system of main skid trails	None
Major - 31 cm to 60 cm of compaction	120 metres	480 metres	If maximum distance is greater than 120 m, cease operations on an individual trail. This may include up to 30 m of extreme compaction for an individual trail. If maximum distance is greater than 480 m, cease operation on the landing. This may include up to 120 m of extreme compaction for a landing
Extreme - compaction greater than 61 cm	30 metres	120 metres	If maximum distance is greater than 30 m, cease operations on an individual trail If maximum distance is greater than 120 m cease operations on the landing

Literature Cited

Canadian Forestry Service. 1988. *Forest inventory terms in Canada*. Third edition. Haddon, B.D. (ed.). Canadian Forest Inventory Committee. Forestry Canada, Ottawa. 109 pp.

OMNR. 1993. *Timber management guidelines for the use of herbicides in the Crown and MNR managed forests of Ontario*. Ministry of Natural Resources, Sault Ste Marie, ON. 5 pp.

OMNR. 1996. *Forest Management Planning Manual for Ontario's Crown Forests*. Queen's Printer for Ontario. Toronto. 452 pp.

APPENDIX A

FEC Field Guide Listing

Ecosite Fact Sheet Field Guide Listing

The following MNR ***Field Guides*** describe the understory vegetation, geographic distribution, climatic data and soil-landform characteristics for each ecosite and site type in Ontario. Fact sheets for central Ontario are described in Chambers *et al.* (1997). Fact sheets for northwestern and northeastern Ontario are described in McCarthy *et al.*(1994) and Racey *et al* (1992) respectively.

For central Ontario ecosites (ES):

Chambers, B.A., B. J. Naylor, J. Nieppola, B. Merchant and P. Uhlig. 1997. *Field guide to forest ecosystems of central Ontario*. Ontario Ministry of Natural Resources, Southcentral Sciences Section, North Bay. SCSS Field Guide FG-01.

For northwestern Ontario ecosites (ES):

Racey, G.D., A.F. Harris, J.L. Jeglum, R.F. Foster and G.M. Wickware. 1996. *Terrestrial and wetland ecosites of northwestern Ontario*. Ontario Ministry of Natural Resources, North West Science and Technology Unit, Thunder Bay. Field Guide FG-02.

For Northeastern Ontario site types (ST):

McCarthy, T.G., R.W. Arnup, J. Nieppola, B.G. Merchant, K.C. Taylor and W.J. Parton. 1994. *Field guide to forest ecosystems of northeastern Ontario*. Ontario Ministry of Natural Resources, North East Science and Technology, Timmins. Field Guide FG-001.

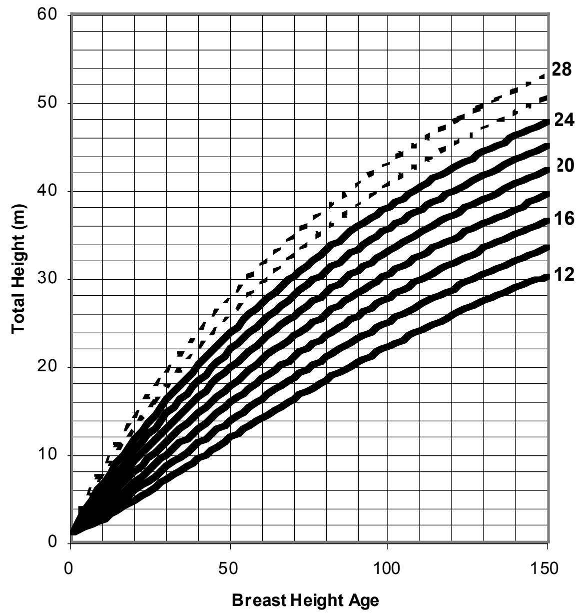
APPENDIX B

Conifer Growth & Yield Factsheets

White Pine Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24	26	28
5	1.95	2.23	2.56	2.94	3.36	3.82	4.33	4.88	5.46
10	2.87	3.42	4.03	4.71	5.43	6.20	7.02	7.88	8.78
15	3.91	4.70	5.57	6.49	7.46	8.48	9.54	10.64	11.77
20	5.01	6.03	7.11	8.25	9.43	10.65	11.92	13.21	14.53
25	6.16	7.38	8.66	9.98	11.34	12.74	14.17	15.63	17.11
30	7.32	8.73	10.18	11.68	13.19	14.75	16.32	17.92	19.54
35	8.50	10.07	11.68	13.33	14.99	16.67	18.37	20.09	21.82
40	9.67	11.40	13.15	14.93	16.72	18.52	20.33	22.16	23.99
45	10.84	12.71	14.59	16.49	18.39	20.29	22.21	24.12	26.04
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00
55	13.14	15.26	17.36	19.47	21.55	23.64	25.72	27.79	29.86
60	14.27	16.49	18.69	20.89	23.06	25.21	27.36	29.50	31.63
65	15.38	17.70	19.99	22.26	24.50	26.73	28.94	31.14	33.32
70	16.46	18.87	21.24	23.59	25.90	28.19	30.46	32.70	34.93
75	17.52	20.02	22.46	24.88	27.24	29.59	31.91	34.20	36.48
80	18.56	21.13	23.64	26.12	28.54	30.93	33.30	35.64	37.95
85	19.57	22.21	24.79	27.32	29.79	32.23	34.64	37.01	39.36
90	20.56	23.26	25.89	28.47	30.99	33.47	35.92	38.33	40.71
95	21.52	24.28	26.97	29.59	32.15	34.67	37.15	39.59	
100	22.46	25.27	28.00	30.67	33.27	35.82	38.33	40.80	
105	23.37	26.23	29.01	31.71	34.34	36.93	39.47		
110	24.25	27.16	29.98	32.72	35.38	37.99	40.56		
115	25.11	28.06	30.91	33.69	36.38	39.02			
120	25.94	28.93	31.82	34.62	37.34	40.00			
125	26.75	29.78	32.69	35.52	38.27	40.95			
130	27.53	30.59	33.54	36.39	39.16				
135	28.29	31.38	34.35	37.23	40.02				
140	29.02	32.14	35.14	38.04	40.84				
145	29.73	32.88	35.90	38.82					
150	30.42	33.59	36.63	39.57					

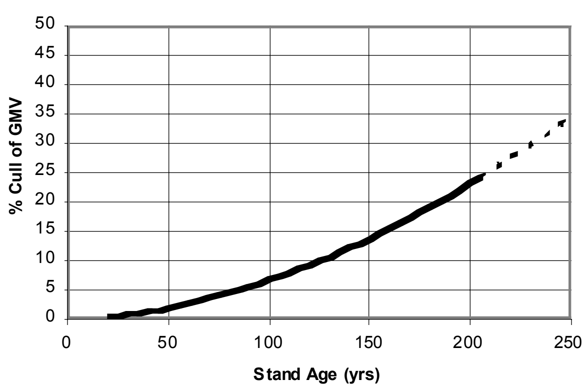
White Pine Site Index Curves



$Ht=1.3+[b1*(SI^{b2})*(1-EXP^{b3*Age})^{b4*(SI^{b5})}]$ b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht 14.4286	0.4764	-0.0081	2.8731	0.3428	0.99	0.99	4.7

Data Source: *Central Ontario* *Based on 58 trees from FEC plots* ***Total Age = Breast Height Age + 6 years***

Cull as a Percent of Gross Merchantable Volume



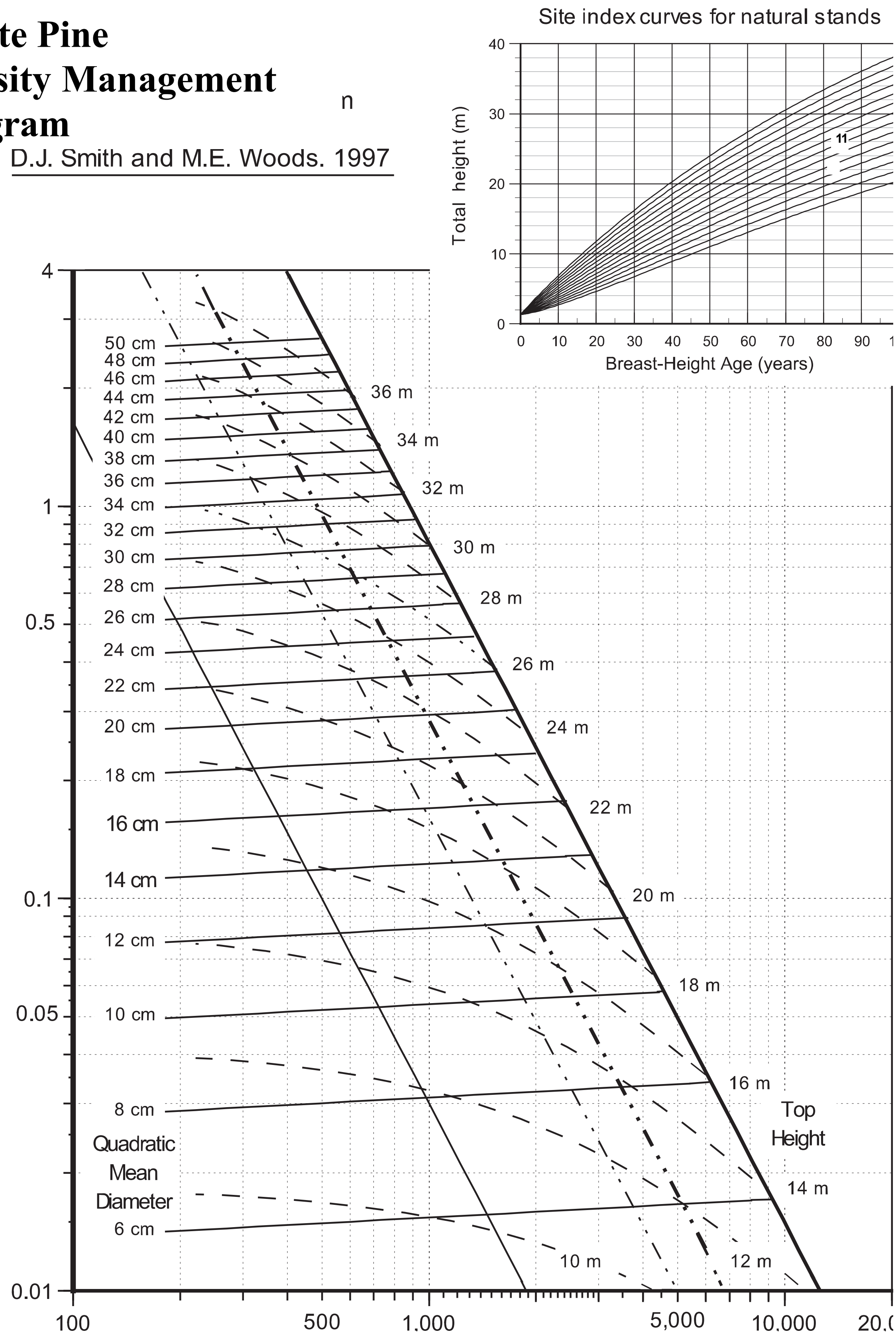
Cull = 0.0018 * Stand Age$^{1.7852}$

Data Source: Basham, J.T. 1991. 1012 Trees

Cull as a % of Gross Merchantable Volume Age	%	Age	%	Age	%
20	0.38	105	7.30	190	21.05
25	0.56	110	7.94	195	22.05
30	0.78	115	8.59	200	23.07
35	1.03	120	9.27	205	24.11
40	1.30	125	9.97	210	25.17
45	1.61	130	10.69	215	26.25
50	1.94	135	11.44	220	27.35
55	2.30	140	12.21	225	28.47
60	2.69	145	12.99	230	29.61
65	3.10	150	13.80	235	30.77
70	3.54	155	14.64	240	31.95
75	4.01	160	15.49	245	33.14
80	4.49	165	16.37	250	34.36
85	5.01	170	17.26	255	35.60
90	5.55	175	18.18	260	36.85
95	6.11	180	19.12	265	38.13
100	6.69	185	20.07	270	39.42

White Pine Density Management Diagram

D.J. Smith and M.E. Woods. 1997



APPENDIX B

White Pine Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0152	0.0225	0.0297	0.0367	0.0435	0.0502	0.0567	0.0631						
12	0.0219	0.0324	0.0428	0.0528	0.0626	0.0722	0.0816	0.0908	0.0998	0.1085				
14	0.0298	0.0442	0.0582	0.0719	0.0853	0.0983	0.1111	0.1236	0.1358	0.1477	0.1594	0.1709		
16	0.0389	0.0577	0.0760	0.0939	0.1114	0.1284	0.1451	0.1614	0.1774	0.1930	0.2082	0.2232		
18	0.0493	0.0730	0.0962	0.1188	0.1409	0.1625	0.1837	0.2043	0.2245	0.2442	0.2635	0.2824	0.3009	0.3190
20	0.0608	0.0901	0.1188	0.1467	0.1740	0.2007	0.2267	0.2522	0.2771	0.3015	0.3254	0.3487	0.3715	0.3939
22			0.1437	0.1775	0.2105	0.2428	0.2744	0.3052	0.3353	0.3648	0.3937	0.4219	0.4495	0.4766
24			0.1710	0.2113	0.2506	0.2890	0.3265	0.3632	0.3991	0.4342	0.4685	0.5021	0.5350	0.5672
26					0.2941	0.3391	0.3832	0.4263	0.4684	0.5096	0.5499	0.5893	0.6279	0.6657
28					0.3410	0.3933	0.4444	0.4944	0.5432	0.5910	0.6377	0.6834	0.7282	0.7720
30					0.3915	0.4515	0.5102	0.5675	0.6236	0.6784	0.7321	0.7846	0.8359	0.8862
32						0.5137	0.5805	0.6457	0.7095	0.7719	0.8329	0.8926	0.9511	1.0083
34						0.5799	0.6553	0.7289	0.8009	0.8714	0.9403	1.0077	1.0737	1.1383
36						0.6502	0.7346	0.8172	0.8979	0.9769	1.0542	1.1298	1.2037	1.2762
38						0.7244	0.8185	0.9105	1.0005	1.0885	1.1745	1.2588	1.3412	1.4219
40						0.8027	0.9070	1.0089	1.1086	1.2061	1.3014	1.3948	1.4861	1.5755
42						0.8850	0.9999	1.1123	1.2222	1.3297	1.4348	1.5377	1.6384	1.7370
44						0.9713	1.0974	1.2208	1.3414	1.4593	1.5747	1.6877	1.7982	1.9064
46						1.0616	1.1995	1.3343	1.4661	1.5950	1.7211	1.8446	1.9654	2.0836
48						1.1559	1.3060	1.4528	1.5963	1.7367	1.8741	2.0085	2.1400	2.2688
50							1.4171	1.5764	1.7321	1.8845	2.0335	2.1793	2.3220	2.4618
52								1.7050	1.8735	2.0382	2.1994	2.3571	2.5115	2.6627
54								1.8387	2.0204	2.1980	2.3719	2.5420	2.7084	2.8714
56								1.9774	2.1728	2.3639	2.5508	2.7337	2.9128	3.0880
58									2.3308	2.5357	2.7363	2.9325	3.1245	3.3126
60										2.7136	2.9282	3.1382	3.3437	3.5450
62										2.8976	3.1267	3.3509	3.5704	3.7852
64										3.0875	3.3317	3.5706	3.8044	4.0334
66										3.2835	3.5432	3.7972	4.0459	4.2894
68										3.4855	3.7611	4.0309	4.2948	4.5533
70											3.9856	4.2715	4.5512	4.8251
72											4.2166	4.5190	4.8150	5.1047
74											4.4542	4.7736	5.0862	5.3923

Honer's (1967) Total cubic metre volume equation

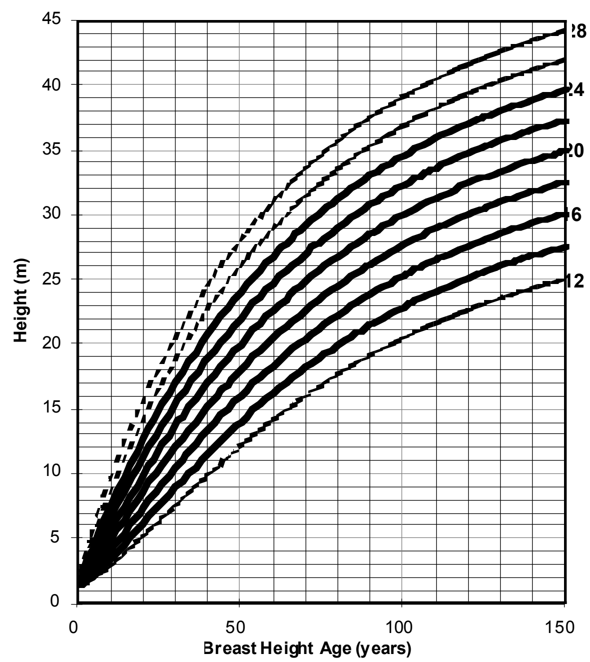
Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.184)^2 / (0.691 + (0.3048*363.676/Height))$ +/- 16.5% Accuracy

——— Denotes range of data 1169 Trees

Red Pine Growth & Yield Factsheet

	Site Index								
Age	12	14	16	18	20	22	24	26	28
5	1.88	2.18	2.54	2.97	3.46	4.00	4.61	5.26	5.97
10	2.81	3.41	4.10	4.86	5.69	6.58	7.54	8.54	9.59
15	3.89	4.77	5.72	6.76	7.85	9.00	10.21	11.46	12.75
20	5.05	6.16	7.35	8.60	9.91	11.27	12.67	14.10	15.58
25	6.24	7.56	8.94	10.38	11.86	13.38	14.94	16.52	18.14
30	7.44	8.94	10.49	12.08	13.70	15.36	17.04	18.74	20.47
35	8.63	10.28	11.97	13.69	15.43	17.20	18.99	20.78	22.60
40	9.79	11.57	13.38	15.21	17.05	18.91	20.79	22.66	24.55
45	10.92	12.82	14.73	16.65	18.57	20.51	22.46	24.39	26.35
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00
55	13.05	15.13	17.21	19.27	21.33	23.39	25.44	27.48	29.53
60	14.05	16.20	18.34	20.47	22.58	24.68	26.78	28.85	30.93
65	15.00	17.22	19.42	21.59	23.74	25.89	28.01	30.12	32.24
70	15.90	18.18	20.42	22.64	24.83	27.01	29.17	31.30	33.44
75	16.76	19.09	21.37	23.62	25.84	28.05	30.23	32.39	34.55
80	17.57	19.94	22.26	24.54	26.79	29.02	31.23	33.40	35.58
85	18.34	20.74	23.09	25.40	27.67	29.92	32.15	34.34	36.54
90	19.06	21.49	23.87	26.20	28.49	30.76	33.01	35.22	37.42
95	19.74	22.20	24.60	26.95	29.26	31.55	33.80	36.03	38.24
100	20.38	22.87	25.29	27.65	29.98	32.28	34.54	36.78	39.00
105	20.98	23.49	25.93	28.31	30.65	32.95	35.23	37.47	39.71
110	21.55	24.07	26.52	28.92	31.27	33.59	35.87	38.12	40.36
115	22.08	24.62	27.08	29.49	31.85	34.17	36.47	38.72	
120	22.58	25.13	27.60	30.02	32.38	34.72	37.02	39.28	
125	23.04	25.61	28.09	30.51	32.89	35.23	37.53	39.80	
130	23.48	26.05	28.55	30.98	33.35	35.70	38.01	40.28	
135	23.89	26.47	28.97	31.41	33.79	36.14	38.46		
140	24.27	26.86	29.37	31.81	34.20	36.55	38.87		
145	24.63	27.22	29.73	32.18	34.57	36.93	39.25		
150	24.96	27.56	30.08	32.53	34.93	37.29	39.61		

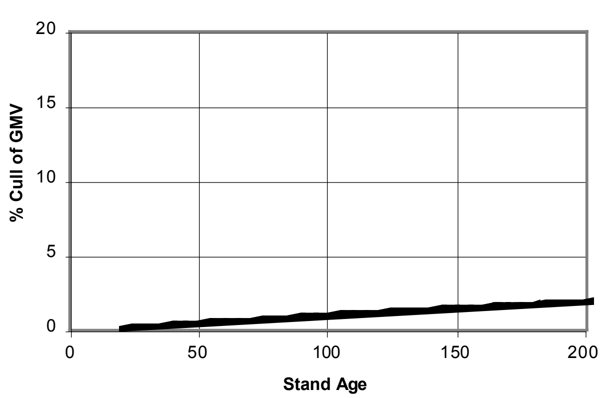
Red Pine Site Index



Ht=1.3+[b1*(SI*^{b2})*(1-EXP$^{b3 *Age}$)$^{b4 *(SI*^b5)}$]						R^2	SE	Maximum difference
	b_1	b_2	b_3	b_4	b_5			
Ht	8.3914	0.5158	-0.0145	4.8468	-0.5094	0.99	0.47	3.2

Data Source: *Central Ontario* *Based on 42 trees from FEC plots* ***Total Age = Breast Height Age + 5 years***

Cull as a Percent of Gross Merchantable Volume



Cull = -0.00001*Age^2 + 0.0121*Age

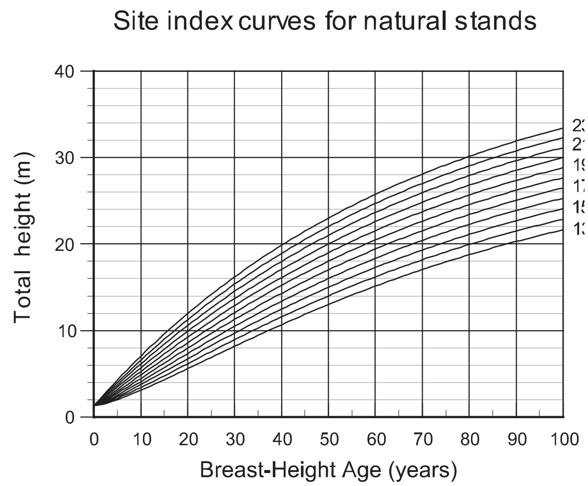
Data Source: Discussion by Basham, J.T. 1991. 462 Trees

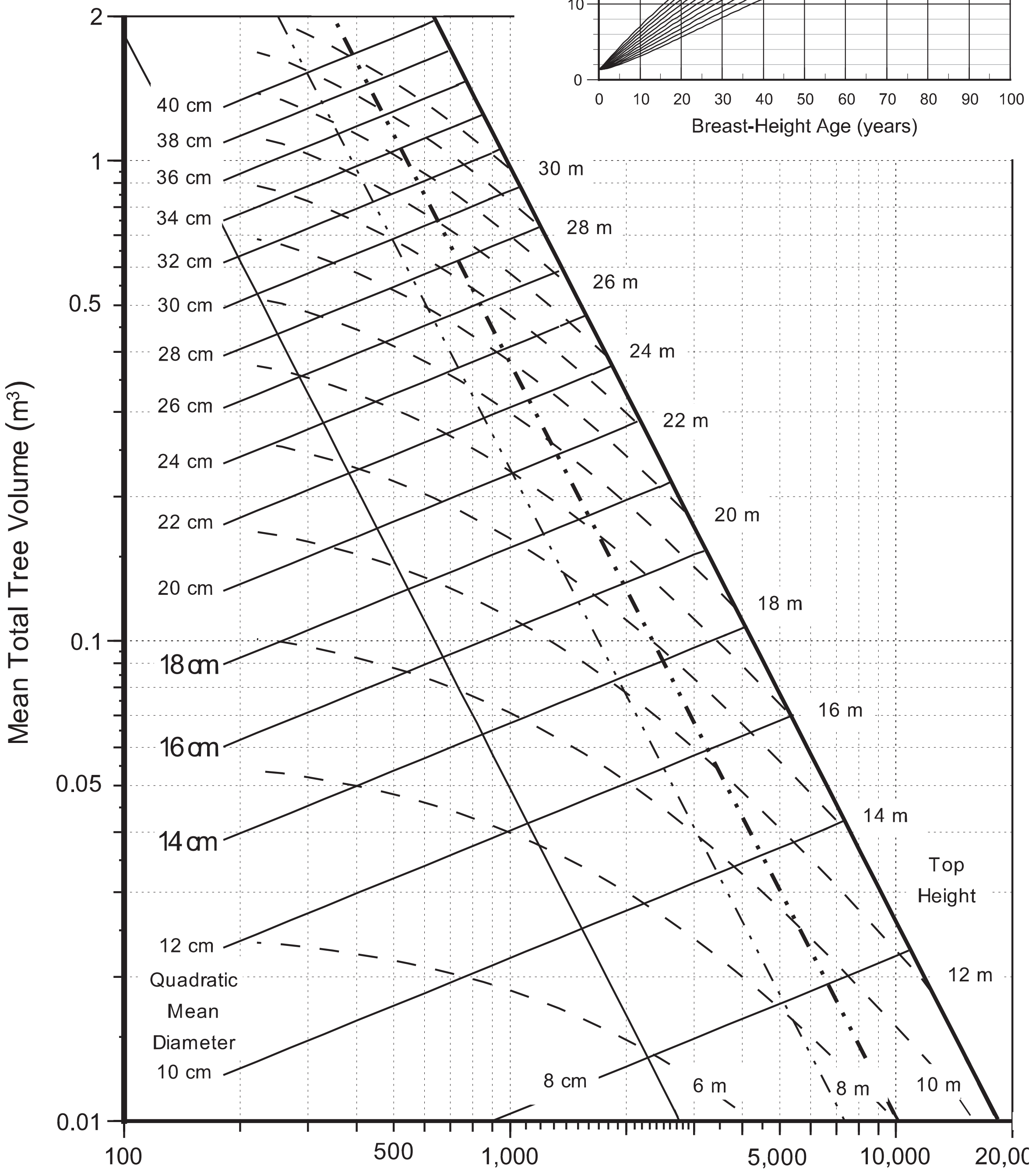
Cull as a % of Gross Merchantable Volume							
Age	%		Age	%		Age	%
20	0.24		105	1.16		190	1.94
25	0.30		110	1.21		195	1.98
30	0.35		115	1.26		200	2.02
35	0.41		120	1.31			
40	0.47		125	1.36			
45	0.52		130	1.40			
50	0.58		135	1.45			
55	0.64		140	1.50			
60	0.69		145	1.54			
65	0.74		150	1.59			
70	0.80		155	1.64			
75	0.85		160	1.68			
80	0.90		165	1.72			
85	0.96		170	1.77			
90	1.01		175	1.81			
95	1.06		180	1.85			
100	1.11		185	1.90			

Red Pine
Density Management
Diagram

m

1997





APPENDIX B

Red Pine Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0231	0.0304	0.0375	0.0445	0.0512	0.0579	0.0643	0.0707					
12	0.0224	0.0332	0.0437	0.0540	0.0640	0.0738	0.0833	0.0927	0.1018	0.1106	0.1193			
14	0.0305	0.0452	0.0595	0.0735	0.0871	0.1004	0.1134	0.1261	0.1385	0.1506	0.1624	0.1740	0.1853	
16	0.0399	0.0591	0.0778	0.0960	0.1138	0.1312	0.1482	0.1647	0.1809	0.1967	0.2122	0.2273	0.2420	
18	0.0505	0.0747	0.0984	0.1215	0.1440	0.1660	0.1875	0.2085	0.2289	0.2490	0.2685	0.2876	0.3063	0.3246
20	0.0623	0.0923	0.1215	0.1500	0.1778	0.2050	0.2315	0.2574	0.2827	0.3074	0.3315	0.3551	0.3782	0.4008
22	0.0754	0.1117	0.1470	0.1815	0.2152	0.2480	0.2801	0.3114	0.3420	0.3719	0.4011	0.4297	0.4576	0.4849
24		0.1329	0.1750	0.2160	0.2561	0.2952	0.3333	0.3706	0.4070	0.4426	0.4774	0.5114	0.5446	0.5771
26		0.1559	0.2053	0.2535	0.3005	0.3464	0.3912	0.4350	0.4777	0.5194	0.5602	0.6001	0.6391	0.6773
28			0.2382	0.2940	0.3485	0.4018	0.4537	0.5044	0.5540	0.6024	0.6497	0.6960	0.7413	0.7855
30			0.2734	0.3375	0.4001	0.4612	0.5208	0.5791	0.6360	0.6916	0.7459	0.7990	0.8509	0.9017
32			0.3111	0.3840	0.4552	0.5247	0.5926	0.6589	0.7236	0.7868	0.8486	0.9091	0.9682	1.0260
34				0.4335	0.5139	0.5924	0.6690	0.7438	0.8169	0.8883	0.9580	1.0263	1.0930	1.1582
36				0.4860	0.5762	0.6641	0.7500	0.8339	0.9158	0.9958	1.0741	1.1506	1.2253	1.2985
38				0.5416	0.6420	0.7400	0.8357	0.9291	1.0204	1.1096	1.1967	1.2819	1.3653	1.4468
40					0.7113	0.8199	0.9259	1.0295	1.1306	1.2294	1.3260	1.4204	1.5128	1.6031
42					0.7842	0.9040	1.0208	1.1350	1.2465	1.3554	1.4619	1.5660	1.6678	1.7674
44					0.8607	0.9921	1.1204	1.2457	1.3680	1.4876	1.6045	1.7187	1.8304	1.9397
46					0.9407	1.0843	1.2246	1.3615	1.4952	1.6259	1.7537	1.8785	2.0006	2.1201
48					1.0243	1.1807	1.3334	1.4824	1.6281	1.7704	1.9095	2.0454	2.1784	2.3084
50					1.1114	1.2811	1.4468	1.6086	1.7666	1.9210	2.0719	2.2194	2.3637	2.5048
52					1.2021	1.3857	1.5648	1.7398	1.9107	2.0777	2.2410	2.4005	2.5566	2.7092
54					1.2964	1.4943	1.6875	1.8762	2.0605	2.2406	2.4167	2.5887	2.7570	2.9216
56					1.3942	1.6070	1.8148	2.0178	2.2160	2.4097	2.5990	2.7841	2.9650	3.1420
58					1.4956	1.7239	1.9468	2.1645	2.3771	2.5849	2.7879	2.9865	3.1806	3.3705
60					1.6005	1.8448	2.0834	2.3163	2.5439	2.7662	2.9835	3.1960	3.4037	3.6069
62							2.2246	2.4733	2.7163	2.9537	3.1857	3.4126	3.6344	3.8514
64									2.8944	3.1473	3.3946	3.6363	3.8727	4.1039
66									3.0781	3.3471	3.6101	3.8671	4.1185	4.3644
68												4.1051	4.3719	4.6329
70												4.3501	4.6328	4.9094
72												4.6022	4.9014	5.1940
74												4.8614	5.1774	5.4865

Honer's (1967) Total cubic metre volume equation

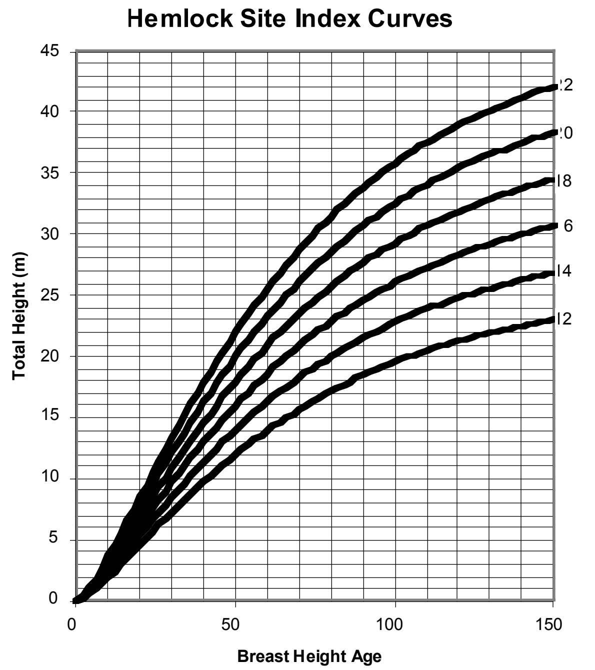
04365*0.151)^2 / (0.710 +(0.3048*355.623/Height))   +/- 17.3% Accuracy

——— Denotes range of data   1333 Trees

APPENDIX B

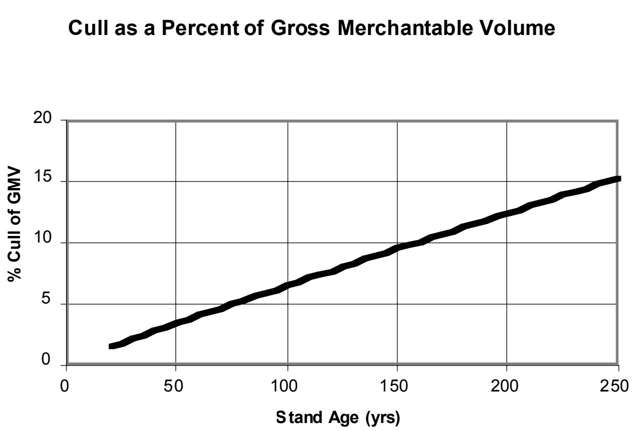
Eastern Hemlock Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22
5	0.57	0.87	1.22	1.63	2.09	2.59
10	1.68	2.33	3.05	3.83	4.66	5.53
15	3.02	3.99	5.02	6.10	7.22	8.36
20	4.45	5.69	6.97	8.29	9.63	10.99
25	5.88	7.34	8.83	10.34	11.85	13.38
30	7.28	8.91	10.57	12.22	13.88	15.53
35	8.59	10.38	12.16	13.94	15.70	17.45
40	9.81	11.72	13.61	15.48	17.33	19.17
45	10.94	12.94	14.92	16.87	18.79	20.69
50	11.96	14.05	16.09	18.10	20.08	22.03
55	12.89	15.04	17.14	19.20	21.23	23.22
60	13.72	15.92	18.07	20.18	22.24	24.26
65	14.47	16.72	18.90	21.04	23.13	25.18
70	15.14	17.42	19.64	21.80	23.92	25.99
75	15.73	18.04	20.29	22.47	24.61	26.70
80	16.25	18.59	20.86	23.07	25.22	27.33
85	16.72	19.08	21.36	23.59	25.76	27.88
90	17.13	19.51	21.81	24.04	26.23	28.36
95	17.49	19.88	22.20	24.45	26.64	28.78
100	17.81	20.22	22.54	24.80	27.00	29.15
105	18.10	20.51	22.84	25.11	27.32	29.47
110	18.34	20.77	23.11	25.38	27.59	29.76
115	18.56	20.99	23.34	25.62	27.84	30.00
120	18.75	21.19	23.54	25.83	28.05	30.22
125	18.92	21.36	23.72	26.01	28.24	30.41
130	19.07	21.51	23.88	26.17	28.40	30.58
135	19.20	21.65	24.01	26.31	28.54	30.72
140	19.31	21.76	24.13	26.43	28.67	30.85
145	19.41	21.87	24.24	26.54	28.78	30.96
150	19.50	21.95	24.33	26.63	28.87	31.06



Ht=[b1*(SI*.3048^{b2})*(1-EXP$^{b3 *Age}$)$^{b4 *(SI*.3048^b5)}$] *.3048	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	2.1419	0.9979	-0.0175	1.4086	-0.0008	0.99	0.15	0.5
SI	0.2172	1.1309	-0.0105	-1.9120	-0.1327	0.99	0.37	1.0

Data Source: *Frothingham 1915* *Based on average of "maximum" height growth curves from stands in New York, Mich., and S. Appalachan Mountains* ***Add 6years to dbh age to obtain total age.***
Number of plots and dominant trees not given.

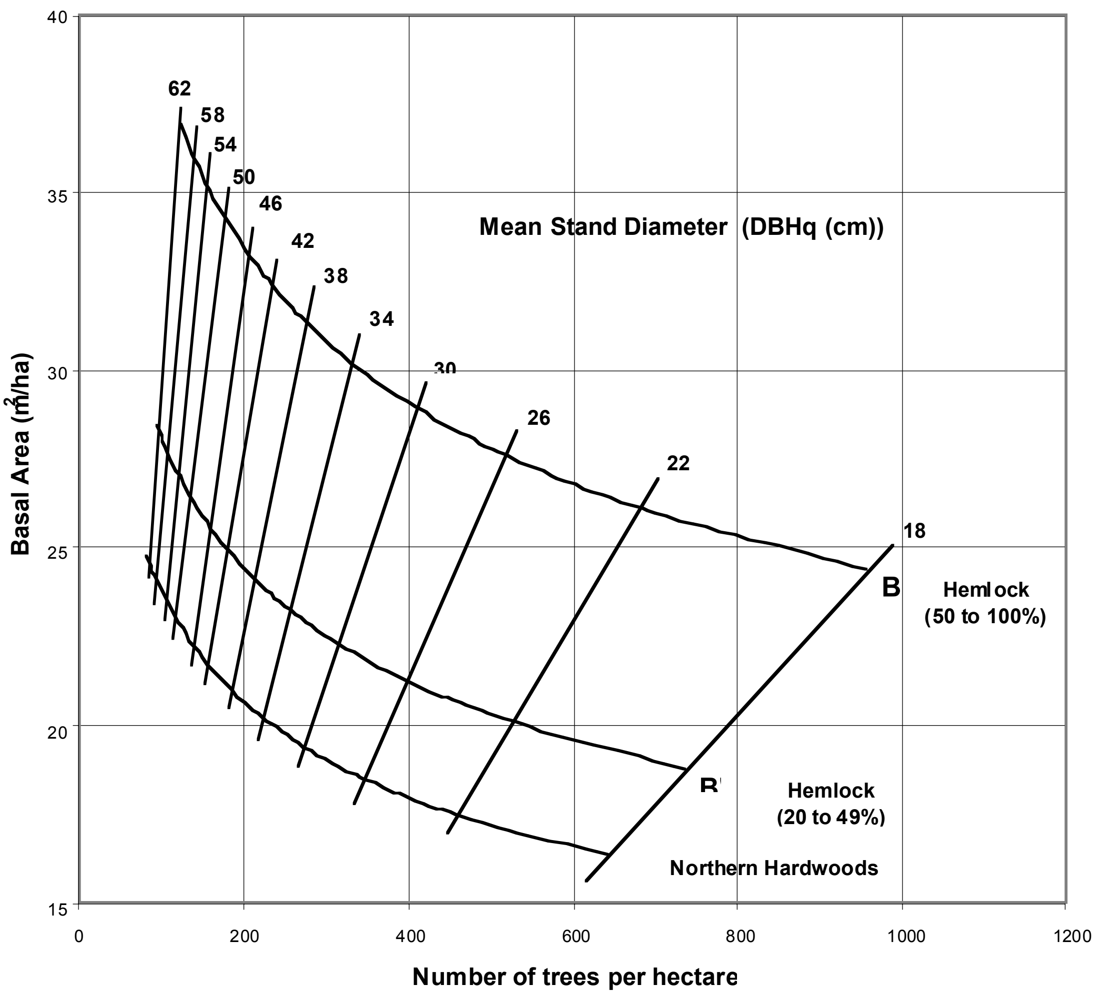


Cull = = 0.0892 * Stand Age$^{0.9326}$

Data Source: Basham, J.T. 1991. 387 Trees

Cull as a % of Gross Merchantable Volume					
Age	%	Age	%	Age	%
20	1.46	105	6.84	190	11.90
25	1.80	110	7.15	195	12.19
30	2.13	115	7.45	200	12.48
35	2.46	120	7.75	205	12.77
40	2.78	125	8.05	210	13.06
45	3.11	130	8.35	215	13.35
50	3.43	135	8.65	220	13.64
55	3.74	140	8.95	225	13.93
60	4.06	145	9.25	230	14.22
65	4.38	150	9.55	235	14.51
70	4.69	155	9.84	240	14.80
75	5.00	160	10.14	245	15.08
80	5.31	165	10.43	250	15.37
85	5.62	170	10.73	255	15.66
90	5.93	175	11.02	260	15.94
95	6.23	180	11.31	265	16.23
100	6.54	185	11.61	270	16.51

Hemlock Stocking Guide



(Based on Tubbs 1977)

	B Line Hemlock (50 - 100%)		B' Line Hemlock (20 - 49%)		Northern Hardwoods	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	957	24.4	737	18.8	641	16.3
22	686	26.1	528	20.1	459	17.5
26	519	27.6	400	21.2	348	18.5
30	409	28.9	315	22.3	274	19.4
34	333	30.2	256	23.2	223	20.2
38	276	31.3	213	24.1	185	21.0
42	234	32.4	180	25.0	157	21.7
46	201	33.4	155	25.7	135	22.4
50	175	34.4	135	26.5	117	23.0
54	154	35.3	119	27.2	103	23.6
58	137	36.1	105	27.8	92	24.2

Eastern Hemlock Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0229	0.0300	0.0367	0.0433	0.0496	0.0556	0.0615	0.0672	0.0726	0.0779	0.0830	0.0880	0.0927
12	0.0224	0.0330	0.0431	0.0529	0.0623	0.0714	0.0801	0.0886	0.0967	0.1046	0.1122	0.1195	0.1267	0.1335
14	0.0305	0.0449	0.0587	0.0720	0.0848	0.0972	0.1091	0.1205	0.1316	0.1423	0.1527	0.1627	0.1724	0.1818
16	0.0399	0.0587	0.0767	0.0941	0.1108	0.1269	0.1425	0.1574	0.1719	0.1859	0.1994	0.2125	0.2252	0.2374
18	0.0505	0.0742	0.0971	0.1191	0.1402	0.1606	0.1803	0.1993	0.2176	0.2353	0.2524	0.2690	0.2850	0.3005
20	0.0623	0.0917	0.1199	0.1470	0.1731	0.1983	0.2226	0.2460	0.2686	0.2905	0.3116	0.3320	0.3518	0.3710
22	0.0754	0.1109	0.1450	0.1779	0.2095	0.2399	0.2693	0.2977	0.3250	0.3515	0.3770	0.4018	0.4257	0.4489
24	0.0897	0.1320	0.1726	0.2117	0.2493	0.2856	0.3205	0.3543	0.3868	0.4183	0.4487	0.4781	0.5066	0.5342
26	0.1053	0.1549	0.2026	0.2484	0.2926	0.3351	0.3762	0.4158	0.4540	0.4909	0.5266	0.5611	0.5946	0.6269
28	0.1222	0.1796	0.2349	0.2881	0.3393	0.3887	0.4363	0.4822	0.5265	0.5693	0.6107	0.6508	0.6895	0.7271
30		0.2062	0.2697	0.3307	0.3895	0.4462	0.5008	0.5535	0.6044	0.6536	0.7011	0.7471	0.7916	0.8346
32		0.2346	0.3068	0.3763	0.4432	0.5077	0.5698	0.6298	0.6877	0.7436	0.7977	0.8500	0.9006	0.9496
34			0.3464	0.4248	0.5003	0.5731	0.6433	0.7110	0.7763	0.8395	0.9005	0.9596	1.0167	1.0721
36				0.4763	0.5609	0.6425	0.7212	0.7971	0.8704	0.9412	1.0096	1.0758	1.1399	1.2019
38				0.5306	0.6250	0.7159	0.8035	0.8881	0.9698	1.0486	1.1249	1.1987	1.2700	1.3391
40				0.5880	0.6925	0.7932	0.8903	0.9840	1.0745	1.1619	1.2464	1.3282	1.4072	1.4838
42					0.7635	0.8745	0.9816	1.0849	1.1847	1.2810	1.3742	1.4643	1.5515	1.6359
44					0.8379	0.9598	1.0773	1.1907	1.3002	1.4059	1.5082	1.6071	1.7028	1.7954
46					0.9158	1.0490	1.1775	1.3014	1.4211	1.5367	1.6484	1.7565	1.8611	1.9624
48					0.9972	1.1422	1.2821	1.4170	1.5473	1.6732	1.7949	1.9125	2.0264	2.1367
50					1.0820	1.2394	1.3911	1.5376	1.6789	1.8155	1.9475	2.0752	2.1988	2.3185
52						1.3405	1.5047	1.6630	1.8159	1.9637	2.1065	2.2446	2.3782	2.5077
54						1.4456	1.6226	1.7934	1.9583	2.1176	2.2716	2.4206	2.5647	2.7043
56						1.5547	1.7450	1.9287	2.1061	2.2774	2.4430	2.6032	2.7582	2.9083
58							1.8719	2.0689	2.2592	2.4430	2.6206	2.7924	2.9587	3.1197
60							2.0032	2.2141	2.4177	2.6143	2.8045	2.9883	3.1663	3.3386
62								2.3642	2.5815	2.7915	2.9945	3.1909	3.3809	3.5649
64										2.9745	3.1909	3.4001	3.6025	3.7986
66										3.1634	3.3934	3.6159	3.8312	4.0397
68										3.3580	3.6022	3.8384	4.0669	4.2882
70										3.5584	3.8172	4.0675	4.3097	4.5442
72										3.7647	4.0384	4.3032	4.5595	4.8076
74										3.9767	4.2659	4.5456	4.8163	5.0784

Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.155)^2 / (1.112+(0.3048 \cdot 350.092/Height))$ +/- 23.6% Accuracy

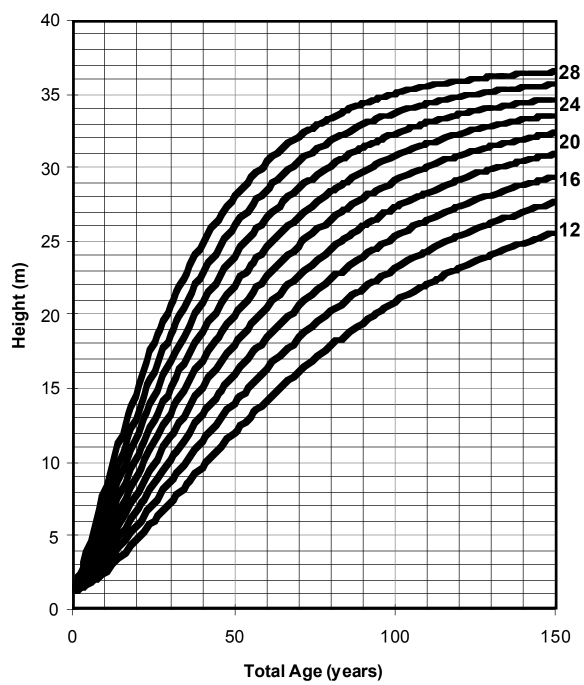
——— Denotes range of data 383 Trees

APPENDIX B

White Spruce Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24	26	28
5	1.77	1.96	2.19	2.46	2.77	3.12	3.53	3.99	4.53
10	2.62	3.08	3.60	4.18	4.83	5.55	6.35	7.26	8.28
15	3.66	4.39	5.18	6.06	7.02	8.06	9.20	10.46	11.86
20	4.81	5.79	6.84	7.98	9.20	10.51	11.92	13.45	15.12
25	6.01	7.22	8.50	9.87	11.31	12.83	14.46	16.18	18.04
30	7.24	8.65	10.14	11.69	13.31	15.00	16.78	18.64	20.61
35	8.46	10.06	11.71	13.42	15.18	17.00	18.88	20.83	22.87
40	9.67	11.43	13.22	15.05	16.92	18.83	20.78	22.78	24.83
45	10.86	12.74	14.65	16.58	18.52	20.49	22.48	24.49	26.53
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00
55	13.10	15.19	17.27	19.32	21.35	23.36	25.35	27.32	29.27
60	14.16	16.32	18.45	20.54	22.58	24.59	26.56	28.48	30.36
65	15.16	17.39	19.55	21.66	23.70	25.69	27.62	29.49	31.30
70	16.12	18.39	20.58	22.69	24.72	26.68	28.57	30.38	32.11
75	17.03	19.33	21.53	23.63	25.65	27.57	29.41	31.15	32.80
80	17.89	20.21	22.41	24.50	26.48	28.36	30.14	31.82	33.39
85	18.70	21.03	23.22	25.29	27.24	29.07	30.80	32.40	33.90
90	19.46	21.79	23.97	26.01	27.92	29.71	31.37	32.91	34.33
95	20.18	22.50	24.66	26.67	28.54	30.27	31.88	33.35	34.70
100	20.85	23.17	25.30	27.27	29.10	30.78	32.32	33.74	35.02
105	21.49	23.78	25.89	27.82	29.60	31.23	32.72	34.07	35.30
110	22.08	24.35	26.42	28.32	30.05	31.63	33.06	34.36	35.53
115	22.63	24.88	26.92	28.77	30.46	31.99	33.37	34.61	35.73
120	23.15	25.37	27.37	29.19	30.82	32.30	33.63	34.83	35.90
125	23.63	25.82	27.79	29.56	31.15	32.59	33.87	35.02	36.04
130	24.09	26.24	28.17	29.90	31.45	32.84	34.08	35.18	36.17
135	24.51	26.63	28.52	30.21	31.72	33.06	34.26	35.33	36.27
140	24.90	26.99	28.84	30.49	31.95	33.26	34.42	35.45	36.36
145	25.27	27.32	29.14	30.74	32.17	33.44	34.56	35.56	36.44
150	25.61	27.63	29.41	30.98	32.36	33.59	34.68	35.65	36.51

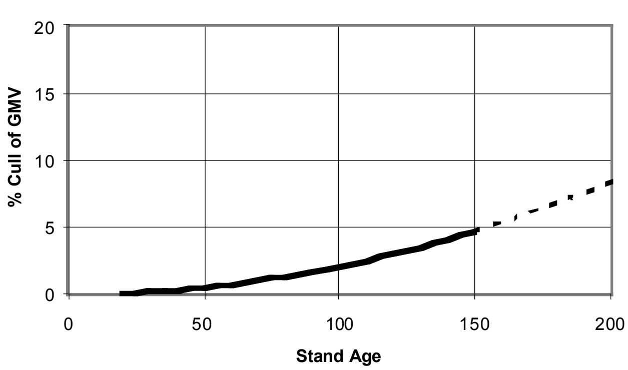
White Spruce Site Index



	Refer to Almemdag 1991 b_1	b_2	b_3	b_4	R^2	SE	Maximum difference
Ht	16.5383	0.2336	2.8896	-0.2556	0.95	NA	NA
SI	40.6506	5.6605	1.2544	-0.1567	0.78	NA	NA

Data Source: Almemdag 1991 National site-index and height growth curves for white spruce growing in natural stands in Canada. Based on 12,358 observations (169 Ont.)

Cull as a % of Gross Merchantable Volume



Cull = 0.0002 * Stand Age$^{2.0079}$

Data Source: Basham, J.T. 1991. 564 Trees

Cull as a % of Gross Merchantable Volume					
Age	%	Age	%	Age	%
20	0.08	105	2.29	190	7.53
25	0.13	110	2.51	195	7.93
30	0.18	115	2.75	200	8.34
35	0.25	120	2.99		
40	0.33	125	3.25		
45	0.42	130	3.51		
50	0.52	135	3.79		
55	0.62	140	4.08		
60	0.74	145	4.37		
65	0.87	150	4.68		
70	1.01	155	5.00		
75	1.16	160	5.33		
80	1.33	165	5.67		
85	1.50	170	6.02		
90	1.68	175	6.38		
95	1.87	180	6.75		
100	2.07	185	7.13		

White Spruce Standard Volume Table (m^3)

Dbh (cm)	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Total Tree Height (m)													
10	0.0157	0.0230	0.0299	0.0364	0.0427	0.0486	0.0543	0.0597	0.0649					
12	0.0226	0.0331	0.0430	0.0524	0.0614	0.0700	0.0782	0.0860	0.0935	0.1007				
14	0.0308	0.0450	0.0585	0.0714	0.0836	0.0953	0.1064	0.1171	0.1273	0.1371	0.1464			
16	0.0402	0.0588	0.0764	0.0932	0.1092	0.1245	0.1390	0.1529	0.1663	0.1790	0.1912	0.2030		
18	0.0509	0.0744	0.0967	0.1180	0.1382	0.1575	0.1760	0.1936	0.2104	0.2266	0.2420	0.2569	0.2711	
20	0.0628	0.0918	0.1194	0.1456	0.1706	0.1945	0.2172	0.2390	0.2598	0.2797	0.2988	0.3171	0.3347	0.3516
22	0.0760	0.1111	0.1445	0.1762	0.2065	0.2353	0.2628	0.2892	0.3143	0.3384	0.3616	0.3837	0.4050	0.4255
24		0.1323	0.1720	0.2097	0.2457	0.2800	0.3128	0.3441	0.3741	0.4028	0.4303	0.4567	0.4820	0.5063
26			0.2018	0.2461	0.2884	0.3287	0.3671	0.4039	0.4390	0.4727	0.5050	0.5359	0.5657	0.5942
28			0.2341	0.2855	0.3344	0.3812	0.4258	0.4684	0.5092	0.5482	0.5857	0.6216	0.6561	0.6892
30			0.2687	0.3277	0.3839	0.4376	0.4888	0.5377	0.5845	0.6293	0.6723	0.7135	0.7531	0.7912
32			0.3057	0.3729	0.4368	0.4978	0.5561	0.6118	0.6650	0.7160	0.7649	0.8118	0.8569	0.9002
34				0.4209	0.4931	0.5620	0.6278	0.6906	0.7508	0.8083	0.8635	0.9165	0.9673	1.0162
36				0.4719	0.5529	0.6301	0.7038	0.7743	0.8417	0.9062	0.9681	1.0275	1.0845	1.1393
38				0.5258	0.6160	0.7020	0.7842	0.8627	0.9378	1.0097	1.0787	1.1448	1.2083	1.2694
40				0.5826	0.6825	0.7779	0.8689	0.9559	1.0391	1.1188	1.1952	1.2685	1.3389	1.4065
42				0.6423	0.7525	0.8576	0.9580	1.0539	1.1456	1.2335	1.3177	1.3985	1.4761	1.5507
44					0.8259	0.9412	1.0514	1.1566	1.2573	1.3538	1.4462	1.5349	1.6200	1.7019
46					0.9027	1.0287	1.1491	1.2642	1.3742	1.4796	1.5807	1.6776	1.7707	1.8601
48					0.9829	1.1201	1.2512	1.3765	1.4963	1.6111	1.7211	1.8267	1.9280	2.0254
50						1.2154	1.3577	1.4936	1.6236	1.7482	1.8675	1.9820	2.0920	2.1977
52						1.3146	1.4684	1.6155	1.7561	1.8908	2.0199	2.1438	2.2627	2.3770
54						1.4177	1.5836	1.7421	1.8938	2.0391	2.1783	2.3119	2.4401	2.5634
56								1.8735	2.0367	2.1929	2.3426	2.4863	2.6242	2.7567
58									2.1847	2.3523	2.5129	2.6670	2.8150	2.9572
60									2.3380	2.5173	2.6892	2.8541	3.0125	3.1646
62									2.4965	2.6880	2.8715	3.0476	3.2167	3.3791
64									2.6601	2.8642	3.0598	3.2474	3.4275	3.6007
66										3.0460	3.2540	3.4535	3.6451	3.8292
68										3.2334	3.4542	3.6660	3.8694	4.0648
70										3.4264	3.6604	3.8848	4.1003	4.3074
72										3.6250	3.8725	4.1100	4.3380	4.5571
74										3.8292	4.0906	4.3415	4.5823	4.8138

Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.176)^2 / (1.44+(0.3048*342.175/Height))$

+/- 17.9 % Accuracy

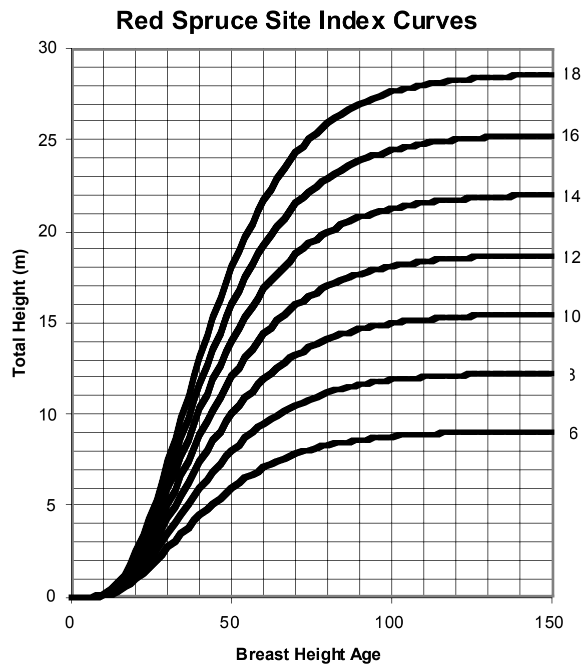
——— Denotes range of data

2692 Trees

APPENDIX B

Red Spruce Growth & Yield Factsheet

	Site Index						
Age	**6**	**8**	**10**	**12**	**14**	**16**	**18**
5	0.01	0.01	0.01	0.01	0.01	0.01	0.0
10	0.11	0.13	0.14	0.16	0.18	0.19	0.2
15	0.43	0.53	0.62	0.71	0.80	0.88	1.0
20	1.01	1.28	1.54	1.79	2.03	2.27	2.5
25	1.80	2.32	2.83	3.32	3.81	4.28	4.7
30	2.70	3.53	4.34	5.13	5.91	6.69	7.4
35	3.63	4.78	5.91	7.03	8.14	9.24	10.3
40	4.51	5.98	7.43	8.87	10.31	11.74	13.2
45	5.31	7.07	8.82	10.56	12.30	14.04	15.8
50	6.01	8.03	10.04	12.06	14.07	16.08	18.1
55	6.61	8.84	11.09	13.33	15.58	17.84	20.1
60	7.10	9.53	11.96	14.41	16.86	19.31	21.8
65	7.51	10.09	12.68	15.29	17.90	20.53	23.2
70	7.84	10.54	13.27	16.01	18.76	21.52	24.3
75	8.11	10.91	13.74	16.59	19.45	22.32	25.2
80	8.32	11.21	14.12	17.05	20.00	22.96	25.9
85	8.49	11.44	14.42	17.42	20.44	23.47	26.5
90	8.62	11.62	14.66	17.71	20.79	23.88	27.0
95	8.73	11.77	14.84	17.94	21.06	24.20	27.4
100	8.81	11.88	14.99	18.12	21.28	24.45	27.6
105	8.87	11.97	15.11	18.27	21.45	24.65	27.9
110	8.92	12.05	15.20	18.38	21.58	24.81	28.0
115	8.96	12.10	15.27	18.47	21.69	24.93	28.2
120	9.00	12.14	15.33	18.54	21.77	25.02	28.3
125	9.02	12.18	15.37	18.59	21.83	25.10	28.4
130	9.04	12.20	15.40	18.63	21.88	25.16	28.4
135	9.05	12.23	15.43	18.67	21.92	25.20	28.5
140	9.07	12.24	15.45	18.69	21.95	25.24	28.5
145	9.08	12.25	15.47	18.71	21.98	25.27	28.6
150	9.08	12.26	15.48	18.73	22.00	25.29	28.6



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$					R^2	SE	Maximum
	b_1	b_2	b_3	b_4	b_5			difference
Ht	1.3307	1.0442	-0.0496	3.5829	0.0945	0.99	0.36	1.2
SI	0.9333	0.9124	-0.0585	-3.1832	0.2184	0.99	0.28	1.1

Data Source: *Meyer 1929*

Based on average of "maximum" height growth curves from stands in Maine, New Hampshire, and Vermont ***Add 15 years to dbh age to obtain total age.***

201 plots, number of dominant and codominant trees not given

Red Spruce Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0171	0.0250	0.0326	0.0398	0.0468	0.0534	0.0597	0.0658	0.0716	0.0772	0.0826	0.0877	0.0927	0.0975
12	0.0246	0.0361	0.0470	0.0574	0.0673	0.0769	0.0860	0.0947	0.1031	0.1112	0.1189	0.1264	0.1335	0.1404
14	0.0335	0.0491	0.0639	0.0781	0.0917	0.1046	0.1170	0.1289	0.1404	0.1513	0.1618	0.1720	0.1817	0.1911
16	0.0438	0.0641	0.0835	0.1020	0.1197	0.1366	0.1529	0.1684	0.1833	0.1976	0.2114	0.2246	0.2374	0.2496
18	0.0554	0.0811	0.1057	0.1291	0.1515	0.1729	0.1935	0.2131	0.2320	0.2501	0.2675	0.2843	0.3004	0.3159
20		0.1002	0.1305	0.1594	0.1870	0.2135	0.2388	0.2631	0.2864	0.3088	0.3303	0.3510	0.3709	0.3901
22		0.1212	0.1579	0.1929	0.2263	0.2583	0.2890	0.3184	0.3466	0.3737	0.3997	0.4247	0.4488	0.4720
24			0.1879	0.2295	0.2693	0.3074	0.3439	0.3789	0.4125	0.4447	0.4756	0.5054	0.5341	0.5617
26			0.2205	0.2694	0.3161	0.3608	0.4036	0.4447	0.4841	0.5219	0.5582	0.5932	0.6268	0.6592
28				0.3124	0.3666	0.4185	0.4681	0.5157	0.5614	0.6053	0.6474	0.6879	0.7269	0.7645
30				0.3586	0.4209	0.4804	0.5374	0.5920	0.6445	0.6948	0.7432	0.7897	0.8345	0.8776
32				0.4080	0.4788	0.5466	0.6114	0.6736	0.7333	0.7905	0.8456	0.8985	0.9495	0.9985
34				0.4606	0.5406	0.6170	0.6903	0.7604	0.8278	0.8924	0.9546	1.0143	1.0719	1.1273
36				0.5164	0.6060	0.6918	0.7738	0.8525	0.9280	1.0005	1.0702	1.1372	1.2017	1.2638
38				0.5754	0.6752	0.7707	0.8622	0.9499	1.0340	1.1148	1.1924	1.2671	1.3389	1.4081
40					0.7482	0.8540	0.9554	1.0525	1.1457	1.2352	1.3212	1.4039	1.4835	1.5602
42					0.8249	0.9416	1.0533	1.1604	1.2632	1.3618	1.4566	1.5478	1.6356	1.7201
44					0.9053	1.0334	1.1560	1.2735	1.3863	1.4946	1.5987	1.6988	1.7951	1.8879
46						1.1294	1.2635	1.3920	1.5152	1.6336	1.7473	1.8567	1.9620	2.0634
48							1.3757	1.5156	1.6498	1.7787	1.9026	2.0217	2.1363	2.2467
50							1.4928	1.6446	1.7902	1.9300	2.0644	2.1937	2.3180	2.4378
52							1.6146	1.7788	1.9363	2.0875	2.2329	2.3727	2.5072	2.6368
54								1.9182	2.0881	2.2512	2.4079	2.5587	2.7038	2.8435
56								2.0629	2.2456	2.4210	2.5896	2.7517	2.9077	3.0580
58									2.4089	2.5970	2.7779	2.9518	3.1192	3.2804
60									2.5779	2.7792	2.9728	3.1589	3.3380	3.5105
62									2.7526	2.9676	3.1742	3.3730	3.5642	3.7484
64									2.9330	3.1622	3.3823	3.5941	3.7979	3.9942
66									3.1192	3.3629	3.5970	3.8222	4.0389	4.2477
68									3.3111	3.5698	3.8183	4.0574	4.2874	4.5090
70										3.7829	4.0462	4.2996	4.5434	4.7782
72											4.2808	4.5488	4.8067	5.0551
74											4.5219	4.8050	5.0774	5.3398

Honer's (1967) Total cubic metre volume equation

Volume (m^3) = 0.0043891*dbh^2 * $(1\text{-}0.04365\text{*}0.169)^2$ / (1.226+(0.3048*315.832/Height))   +/- 26.3 % Accuracy

——— Denotes range of data   227 Trees

APPENDIX C

Ecosite Local Volume Tables

Ecosite local volume tables are a modification of standard volume tables based on a species DBH-height relationship by ecosite. Incorporation of the local DBH-height relationship eliminates the need to measure tree heights. Volume is based solely on DBH within a determined ecosite. An example of an ecosite local volume table is presented in TABLE 1. A process to develop a local volume table for each ecosite is described below.

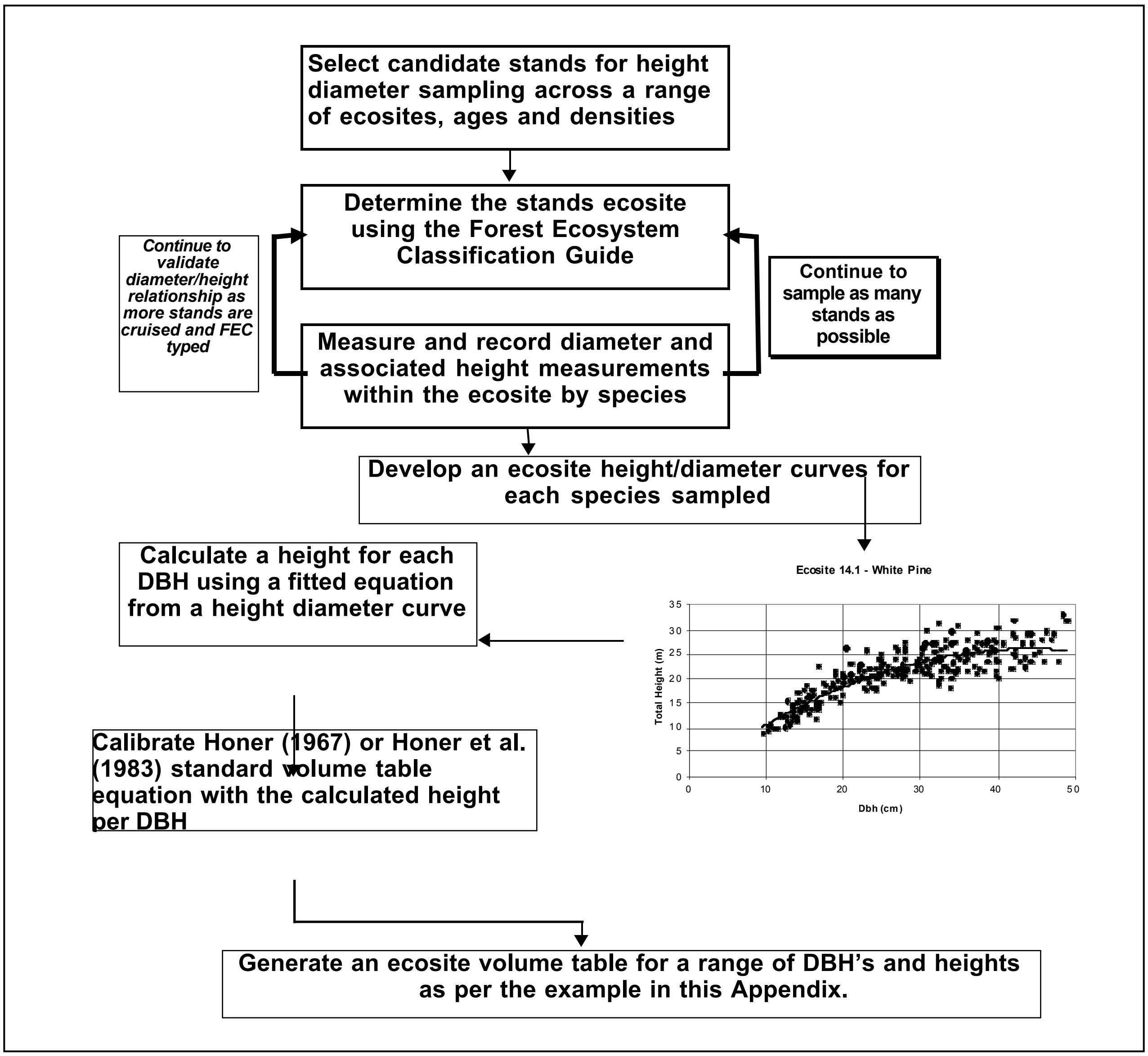


TABLE 1: Example of an ecosite 14.1 and 14.2 local volume table

Ecosite 14.1 and 14.2 Local Volume Table

	White Pine-14.1		White Pine-14.2		Red Oak		Lg Tooth Aspen		Red Pine		White Birch	
Dbh (cm)	Avg. Ht (m)	GTV (m^3/ha)	Avg. Ht (m)	GTV (m^3/ha)	Avg. Ht (m)	GTV (m^3/ha)	Avg. Ht (m)	GTV (m^3/ha)	Avg. Ht (m)	GTV (m^3/ha)	Avg. Ht (m)	GTV (m^3/ha)
10	9.57	0.0352	9.29	0.0342	11.16	0.0407	13.73	0.0463	10.89	0.0406	13.18	0.0471
12	11.15	0.0585	10.59	0.0557	12.17	0.0635	15.04	0.0732	12.42	0.0661	14.40	0.0725
14	12.65	0.0895	11.84	0.0842	13.07	0.0923	16.24	0.1079	13.85	0.0994	15.51	0.1043
16	14.04	0.1288	13.05	0.1204	13.89	0.1275	17.33	0.1508	15.18	0.1413	16.53	0.1425
18	15.34	0.1767	14.22	0.1649	14.63	0.1692	18.34	0.2025	16.43	0.1921	17.46	0.1876
20	16.53	0.2336	15.36	0.2185	15.30	0.2177	19.28	0.2633	17.60	0.2522	18.33	0.2396
22	17.63	0.2996	16.47	0.2817	15.92	0.2731	20.15	0.3338	18.69	0.3221	19.14	0.2986
24	18.64	0.3748	17.55	0.3551	16.50	0.3357	20.97	0.4143	19.72	0.4019	19.90	0.3649
26	19.56	0.4592	18.61	0.4392	17.03	0.4054	21.75	0.5052	20.68	0.4919	20.62	0.4386
28	20.39	0.5527	19.64	0.5345	17.52	0.4825	22.48	0.6066	21.58	0.5922	21.30	0.5196
30	21.15	0.6553	20.65	0.6415	17.98	0.5669	23.17	0.7190	22.42	0.7030	21.94	0.6082
32	21.84	0.7670	21.64	0.7606	18.41	0.6589	23.82	0.8426	23.21	0.8243	22.55	0.7044
34	22.46	0.8874	22.60	0.8923	18.81	0.7583	24.45	0.9777	23.95	0.9562	23.13	0.8083
36	23.02	1.0165	23.55	1.0369	19.19	0.8654	25.04	1.1244	24.64	1.0987	23.68	0.9199
38	23.52	1.1542	24.48	1.1948	19.54	0.9801	25.61	1.2830	25.29	1.2519	24.20	1.0393
40	23.97	1.3002	25.39	1.3664	19.88	1.1025	26.15	1.4536	25.90	1.4158	24.71	1.1666
42	24.38	1.4545	26.28	1.5520	20.19	1.2326	26.67	1.6365	26.47	1.5902		
44	24.74	1.6169	27.16	1.7519	20.49	1.3704	27.17	1.8318	27.01	1.7754		
46	25.07	1.7872	28.02	1.9664	20.77	1.5160	27.64	2.0397	27.51	1.9711		
48	25.35	1.9654	28.86	2.1959	21.03	1.6694	28.10	2.2603	27.98	2.1773		
50	25.61	2.1512	29.69	2.4406	21.29	1.8305	28.54	2.4937	28.43	2.3941		
52	25.84	2.3447	30.51	2.7007	21.53	1.9994	28.96	2.7401	28.84	2.6213		
54	26.04	2.5456	31.31	2.9766	21.75	2.1762	29.37	2.9996	29.23	2.8589		
56	26.22	2.7540	32.10	3.2684	21.97	2.3607	29.76	3.2723	29.60	3.1069		
58	26.38	2.9697	32.88	3.5764	22.17	2.5531	30.14	3.5583	29.94	3.3651		
60	26.53	3.1927	33.64	3.9008	22.37	2.7533	30.51	3.8577	30.27	3.6336		
62	26.65	3.4229	34.40	4.2418	22.55	2.9613	30.86	4.1705	30.57	3.9122		
64	26.76	3.6603	35.14	4.5997	22.73	3.1770	31.20	4.4969	30.85	4.2009		
66	26.86	3.9048	35.86	4.9746	22.90	3.4006	31.53	4.8370	31.12	4.4997		
68	26.95	4.1564	36.58	5.3666	23.06	3.6320	31.85	5.1908	31.37	4.8085		
70	27.02	4.4151	37.29	5.7761	23.21	3.8712	32.16	5.5583	31.61	5.1272		
72	27.09	4.6809	37.98	6.2031	23.36	4.1181	32.46	5.9397	31.83	5.4557		
74	27.15	4.9537	38.67	6.6477	23.50	4.3729	32.75	6.3350	32.03	5.7941		
76	27.20	5.2336	39.34	7.1103	23.63	4.6354	33.03	6.7442	32.23	6.1423		
78	27.24	5.5205	40.01	7.5908	23.76	4.9057	33.30	7.1674	32.41	6.5001		
80	27.28	5.8145	40.66	8.0895	23.88	5.1837	33.57	7.6047	32.59	6.8676		
82	27.32	6.1155	41.31	8.6064	24.00	5.4694	33.83	8.0561	32.75	7.2448		

APPENDIX D

Ecosite Yield Tables

The following flowchart provides a method to develop ecosite yield curves based on forest resource inventory data. An example of an ecosite yield curve developed from this process is shown in FIGURE 2.

FIGURE 1: Development of ecosite yield curves based on forest inventory data

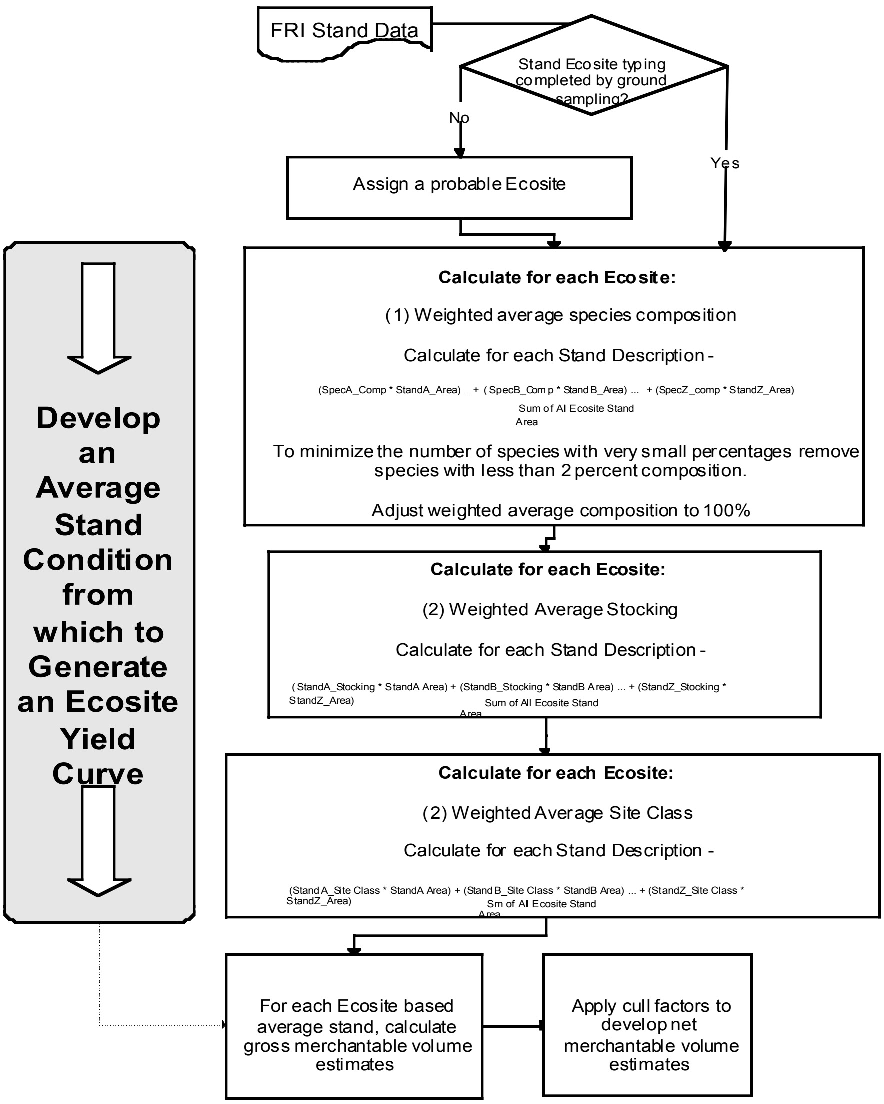
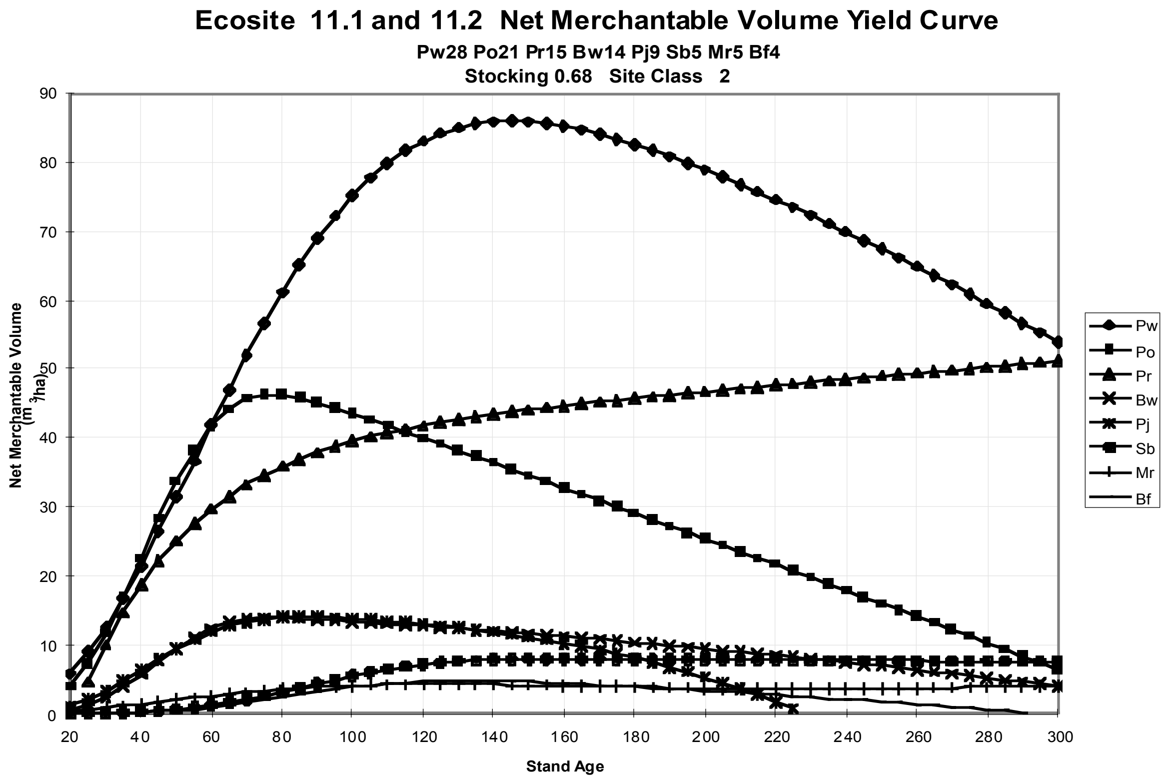


FIGURE 2: Example of an ecosite yield curve based on forest inventory data.



Regional Fully Stocked Ecosite Yield Table based on Weighted Average Species Composition and Site Class

	Pw		Po		Pr		Bw		Pj		Sb		Mr		Bf		All Species	
Stand Age	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha	GMV m^3/ha	NMV m^3/ha
20	8.5	8.5	6.2	5.9			1.0	1.0	1.7	1.7	0.0	0.0	0.7	0.6	0.0	0.0	**18.1**	**17.7**
30	18.8	18.6	18.5	17.1	14.8	14.8	3.7	3.6	4.8	4.8	0.1	0.1	1.5	1.3	0.1	0.1	**62.3**	**60.4**
40	32.0	31.6	36.9	33.1	27.6	27.4	8.6	8.3	9.2	9.2	0.4	0.4	2.5	2.1	0.3	0.3	**117.6**	**112.5**
50	47.2	46.3	56.9	49.4	37.0	36.8	14.5	13.9	13.8	13.8	1.0	1.0	3.8	2.9	0.8	0.7	**175.0**	**164.8**
60	63.3	61.6	73.0	61.4	44.0	43.7	19.3	18.2	17.6	17.4	1.9	1.8	5.1	3.8	1.5	1.4	**225.6**	**209.3**
70	79.2	76.4	82.6	67.1	49.2	48.8	21.6	20.1	20.0	19.6	3.1	3.1	6.5	4.5	2.4	2.3	**264.8**	**242.0**
80	94.0	89.8	86.8	68.0	53.2	52.7	22.3	20.4	21.1	20.5	4.7	4.6	7.8	5.2	3.7	3.4	**293.7**	**264.6**
90	107.3	101.3	88.1	66.4	56.3	55.7	22.4	20.1	21.6	20.6	6.5	6.4	9.0	5.6	5.1	4.5	**316.1**	**280.7**
100	118.5	110.5	88.3	64.0	58.7	58.1	22.4	19.7	21.7	20.3	8.2	8.1	10.0	6.0	6.4	5.6	**334.3**	**292.2**
110	127.6	117.4	88.4	61.4	60.7	59.9	22.4	19.2	21.7	19.8	9.7	9.5	10.8	6.2	7.6	6.4	**348.9**	**299.9**
120	134.7	122.2	88.4	58.8	62.3	61.5	22.4	18.7	21.7	19.2	10.8	10.6	11.5	6.3	8.5	6.9	**360.2**	**304.1**
130	140.0	125.0	88.4	56.1	63.6	62.7	22.4	18.2	21.7	18.4	11.5	11.2	12.0	6.3	9.0	7.1	**368.6**	**305.0**
140	143.8	126.3	88.4	53.5	64.8	63.8	22.4	17.6	21.7	17.5	11.9	11.5	12.3	6.2	9.3	7.0	**374.6**	**303.4**
150	146.5	126.2	88.4	50.8	65.9	64.8	22.4	17.1	21.7	16.4	12.0	11.6	12.6	6.1	9.4	6.8	**378.9**	**299.8**
160	148.2	125.3	88.4	48.1	66.8	65.7	22.4	16.5	21.7	15.1	12.1	11.6	12.8	5.9	9.4	6.5	**381.8**	**294.7**
170	149.4	123.6	88.4	45.4	67.7	66.5	22.4	15.9	21.7	13.6	12.1	11.6	12.9	5.8	9.5	6.1	**384.0**	**288.6**
180	150.1	121.4	88.4	42.7	68.5	67.3	22.4	15.2	21.7	11.9	12.1	11.6	13.0	5.7	9.5	5.8	**385.6**	**281.5**
190	150.5	118.8	88.4	40.0	69.3	68.0	22.4	14.6	21.7	10.0	12.1	11.5	13.0	5.6	9.5	5.3	**386.9**	**273.8**
200	150.7	116.0	88.4	37.3	70.1	68.7	22.4	13.9	21.7	7.8	12.1	11.5	13.0	5.5	9.5	4.9	**387.9**	**265.5**
210	150.9	112.9	88.4	34.6	70.9	69.4	22.4	13.2	21.7	5.4	12.1	11.5	13.0	5.4	9.5	4.5	**388.8**	**256.7**
220	150.9	109.7	88.4	31.8	71.6	70.0	22.4	12.4	21.7	2.6	12.1	11.4	13.1	5.4	9.5	4.0	**389.7**	**247.4**
230	151.0	106.3	88.4	29.1	72.3	70.7	22.4	11.7	21.7		12.1	11.4	13.1	5.3	9.5	3.5	**390.4**	**238.0**
240	151.0	102.8	88.4	26.3	73.0	71.4	22.4	10.9	21.7		12.1	11.4	13.1	5.4	9.5	3.0	**391.2**	**231.1**
250	151.0	99.1	88.4	23.5	73.8	72.0	22.4	10.1	21.7		12.1	11.3	13.1	5.4	9.5	2.5	**391.9**	**224.0**
260	151.0	95.4	88.4	20.8	74.5	72.6	22.4	9.3	21.7		12.1	11.3	13.1	5.5	9.5	2.0	**392.6**	**216.8**
270	151.0	91.5	88.4	18.0	75.2	73.3	22.4	8.5	21.7		12.1	11.3	13.1	5.5	9.5	1.4	**393.4**	**209.4**
280	151.0	87.5	88.4	15.2	75.9	73.9	22.4	7.6	21.7		12.1	11.2	13.1	5.7	9.5	0.8	**394.1**	**201.9**
290	151.0	83.4	88.4	12.4	76.6	74.6	22.4	6.8	21.7		12.1	11.2	13.1	5.8	9.5	0.2	**394.8**	**194.3**
300	151.0	79.2	88.4	9.6	77.3	75.2	22.4	5.9	21.7		12.1	11.1	13.1	6.0	9.5		**395.5**	**187.0**

APPENDIX E

Silvicultural Option Tables

Silvicultural Option Tables

by Fred N.L. Pinto, Al S. Corlett, Brian J. Naylor, Andrée E. Morneault, Dan F. Galley, J. Steve Munro and Jeff Leavey

These option tables have three columns. The left column identifies a specific treatment for a particular silvicultural system, logging method, renewal or maintenance treatment.

The centre column displays a code that identifies the treatment as recommended (**R**), conditionally recommended (**CR**) or not recommended (**NR**). The definitions of these terms are:

R = **Recommended**: This activity is ecologically appropriate (it relates well to the biology of the species and the conditions of the ecosite/site type and minimizes the potential for damage to the physical environment) and will contribute to the achievement of management objectives.

Recommended means that the activity can work based on field experience and current knowledge.

CR = **Conditionally Recommended**: This activity is ecologically appropriate (it relates well to the biology of the species and conditions of the ecosite/site type and minimizes potential for damage to the physical environment) and will contribute to the achievement of management objectives, **only if the conditions or limitations referenced in the comments section are addressed**.

If the conditions or limitations in the comments section are addressed, this practice becomes an approved activity within a silvicultural treatment package.

If this activity is identified in the silvicultural ground rules (SGR) or in a specific silvicultural treatment package (STP), and the conditions or limitations are not addressed, it triggers the “exception” process.

NR = **Not Recommended**: This activity is not ecologically appropriate (it does not relate well to the biology of the species or the conditions of the ecosite/site type, and/or presents undue potential for damage to the physical environment), and/or will not contribute to the achievement of management objectives, and/or is not supported by field experience or current knowledge.

Selection of this activity in the silvicultural ground rules (SGR) or in a specific treatment package (STP) triggers the “exception” process.

The third column of these tables specifies the condition that must be met if a treatment is conditionally recommended or provides additional information about treatments on this ecosite.

The silvicultural option tables are based on the most probable conditions expected on each ecosite. It is recognized that there is a great deal of variability associated with overstory and understory plant abundances within each ecosite. Therefore, it is expected that there may be instances where Great Lakes conifers may be managed on boreal or tolerant hardwood ecosites.

For example, abundant white pine regeneration may be found on a Sugar maple-white birch-poplar-white pine (ES 27) ecosite. The manager may want to manage white pine on this ecosite if it is determined that it is a desirable long-term objective. In this case the manager would use the treatments listed in the silvicultural option tables where white pine is the crop species. Similarly, the treatments listed for the desired Great Lakes conifer species listed in the appropriate silvicultural option table should be used.

Silvicultural options are described individually in the following tables. They may be used alone, for example, a uniform shelterwood harvest may be the only treatment prescribed. They may also be used in combination. For example, a white pine stand may be harvested using a uniform shelterwood regeneration cut followed by mechanical site preparation, chemical site preparation, planting and tending.

Protection options are not listed in these tables. See **Section 3.4.8** "Damaging Agents". Forest managers are advised to consider the use of appropriate silvicultural treatments to prevent damage from occurring.

Silvicultural Options for:

Central Ontario Ecosites: 11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30

Northeast Ontario Site Types: 1, 6b, 6c, 7b, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: white pine (Pw)

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	CR	Use only to restore Pw where white pine is not present and stand conversion is planned or where afforestation of old fields is planned. Open growing conditions may result in severe weevil damage.
Seed-tree	CR	Open growing conditions may result in severe weevil damage. Use where conifer component has a basal area of 4 to 12 m^2/ha. Generally requires the retention of 10 to 35 Pw per hectare. Retain desired veterans. Conditions listed in **Section 7.2.4** apply.
With Standards	CR	Open growing conditions may result in severe weevil damage. Use where stands have 4 m^2/ha basal area of Pw or less. Retain desired veterans. Conditions listed in **Section 7.2.4** apply.
SHELTERWOOD		
Pw Uniform Shelterwood	R	Usually used where basal area > 12 m^2/ha of Pw and a lesser component of Pr, Sw, He or Or. Conditions listed in **Section 7.2.4** apply.
Prep Cut	R	Use to develop thrifty seed-bearers and to remove unwanted species or individuals from the canopy. Stand age usually 61 to 80 years. Crown diameter is usually in the 4 to 5 metre range. Retain dominant and codominant trees of good form and vigour. **Rule of thumb**: full crown spacing of residuals
Regeneration Cut	R	Usually used about 20 years after a prep cut. Crowns may have a diameter of 6 to 8 metres. Crown closure following harvest should be 40 to 50%. **Rule of thumb**: half crown spacing.
First Removal Cut	R	Use after the successful establishment of regeneration 30 cm to 1.5 m in height. Retain 30 to 40% crown closure to protect regeneration against Pw weevil. **Rule of thumb**: full crown spacing.
Final Removal	R	Maintain overstory until regen. is 5 to 6 m tall. Retain desired veterans.
Strip Shelterwood	CR	Conditions listed in **Section 7.2.4** apply. Maximum strip width is usually ½ tree height. Little information is available on long-term results of this technique for Pw stands in Ontario.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	CR	Use only in clear cut silvicultural systems. Not recommended in shelterwood systems because it results in excessive damage to trees and advance regeneration Careful logging practices apply.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30

Northeast Ontario Site Types: 1, 6b, 6c, 7b, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: white pine (Pw)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 30.2		
Mechanical	R	Target is elimination of litter layer, not mineral soil exposure. Must be done while maintaining overstory cover; seedbed must remain moist. Sites with adequate moisture regimes may not necessitate the same level of organic layer removal as on dry sites.
Chemical	R	Controlling competing vegetation early is needed to provide Pw regeneration sufficient light; treatments may be done selectively.
Pre-harvest prescribed burning	CR	Must be low intensity and severity to avoid damaging shallow roots and overstory. Has not been practiced operationally.
Post-harvest prescribed burning	CR	Use only when restoring Pw by clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 17.1, 18.1, 19.1, 19.2 Northeast Site Types: 6b, 6c		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most "x.1" sites have shallow organic mats and coarse soils. Avoid operating machinery in wet conditions to avoid compaction on fine-textured soils (typically "x.2" sites").
Chemical	R	Early vegetation management beneficial to all species on these rich ecosites. Consult hexazinone label for use on coarse soils.
Pre-harvest prescribed burning	CR	Can be used to promote Pw regeneration, but will likely need more than one fire or a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 20.1, 20.2 Northwest ES 24, 18		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats and coarse soils.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30

Northeast Ontario Site Types: 1, 6b, 6c, 7b, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: white pine (Pw)

RENEWAL TREATMENTS		Comments
Chemical	R	Early vegetation management beneficial to all species on these rich ecosites.
Pre-harvest prescribed burning	CR	Can be used to promote Pw, Pr, Sw regeneration, but will likely need more than one fire or a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 21.1 , 21.2		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats and coarse soils. Caution should be used on organic soils in Central Ont. Ecosite 21.2. Slopes may limit the use and choice of equipment.
Chemical	R	Early vegetation management beneficial to Pw. Check hexazinone label for use on these sites.
Pre-harvest prescribed burning	CR	Can be used to promote Pw regeneration, but will likely need a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 14.1 , 14.2		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats. Do not operate machinery in wet conditions to avoid compaction and rutting on silty soils. Slopes may limit equipment choice and use.
Chemical	R	Early vegetation management beneficial to Pw, but advance Or regeneration should be protected.
Pre-harvest prescribed burning	R	Can be used to promote Pw and Or regeneration, but will likely need a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30

Northeast Ontario Site Types: 1, 6b, 6c, 7b, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: white pine (Pw)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 11.1 , 11.2, 12.1, 12.2, 13.1, 13.2 Northwest ES 11, 15		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats, shallow soils and coarse soils.
Chemical	CR	Sites should be surveyed but will likely not need chemical site preparation. If they do, it will likely be targeted at areas with higher levels of competition as opposed to broadcast. Selective tending is probably more appropriate on these relatively low-competition sites.
Pre-harvest prescribed burning	R	Can be used to promote Pw and Pr regeneration
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 16.1		
Mechanical	R	Can be done pre-harvest to promote natural regeneration. Shallow organic mat, shallow soils; scarification treatments should not be deep to avoid erosion and nutrient loss. Slopes and exposed bedrock may limit choice and use of equipment.
Chemical	R	Selective tending treatments likely to be more appropriate.
Pre-harvest prescribed burning	CR	Could be done if low numbers of advance regeneration. However, potential for laddering fuels is high.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Regeneration		
Natural Regeneration	R	Site prepare during a good seed crop.
Planting	R	Plant with medium or large stock .
Seeding	CR	Appropriate site prep and tending required.
TENDING TREATMENTS		
Cleaning	R	If required. When considering herbicide use see **TABLE 7.3.5**
Pruning	R	If required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 14, 16.1, 17.1, 18.1, 19, 20, 21, 30

Northeast Ontario Site Types: 1, 6b, 6c, 7b, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: white pine (Pw)

TENDING TREATMENTS		Comments
Thinning	R	If required.
Improvement cutting	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 11, 12, 13, 17.1, 18.1, 19.1, 20

Northeast Ontario Site Types: 1, 2a, 2b, 3b, 6a, 6b, 7B, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: red pine (Pr)

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	Use to maintain or restore Pr. Retain desired veterans. **Section 7.2.4.3** applies.
Seed-tree	R	Use where Pr is to be maintained or restored to higher stocking and density levels. Use where conifer component has a basal area of 4 to 12 m^2/ha. Generally requires the retention of 10 to 35 Pr per hectare. Retain desired veterans. Conditions listed in **Section 7.2.4** apply.
With Standards	R	Use where Pr is to be maintained or restored to higher stocking and density levels. Use where stands have 4 m^2/ha basal area of Pr or less. Retain desired veterans. Conditions listed in **Section 7.2.4** apply.
Strip	CR	Use in dense stands where the use of the uniform shelterwood system would result in windthrow and damage to residuals.
SHELTERWOOD		
Pr Uniform Shelterwood	R	Pr regeneration must be released promptly so that more shade tolerant species will not dominate. Conditions listed in **Section 7.2.4** apply.
Prep Cut	R	Not necessary in stands with fully developed crowns. Follow the same procedures and intensity of harvest as Pw.
Seed Cut	R	Retain dominant and codominant Pr. Maintain 35 per cent crown closure. Rule of thumb: full crown spacing.
Removal Cut	R	Can occur when seedlings are at least 1 m. Retain desired veterans. **Section 7.2.4.3** applies.
LOGGING METHOD		
Tree-Length and Log Length	R	Careful logging practices apply.
Full Tree	CR	Use only in clear cut silvicultural systems. Careful logging practices apply.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 17.1, 18.1, 19.1, 20

Northeast Ontario Site Types: 1, 2a, 2b, 3b, 6a, 6b, 7B, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: red pine (Pr)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 17.1, 17.2, 18.1, 18.2, 19.1, 19.2 Northeast Site Type 3b, 6a, 6b		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most "x.1" ecosites have shallow organic mats and coarse soils. Avoid operating machinery when soils are wet to avoid compaction on fine-textured soils, typically ecosites with a "x.2".
Chemical	R	Early vegetation management beneficial to all species on these rich ecosites. Consult label for hexazinone for use on coarse soils.
Pre-harvest prescribed burning	CR	Can be used to possibly promote Pr regeneration, but will likely need more than one fire or a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Site Preparation Central Ontario ES 20.1, 20.2 Northwest ES 18, 24		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats and coarse soils.
Chemical	R	Early vegetation management beneficial to all species on these rich ecosites.
Pre-harvest prescribed burning	CR	Can be used to possibly promote Pr regeneration, but will likely need more than one fire or a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 11, 12, 13, 17.1, 18.1, 19.1, 20

Northeast Ontario Site Types: 1, 2a, 2b, 3b, 6a, 6b, 7B, 15

Northwest Ontario Ecosites: 11, 15, 18, 24

Crop Species Objective: red pine (Pr)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 11.1, 11.2, 12.1, 12.2, 13.1, 13.2 Northeast Site Type 2a, 2b Northwest ES 11, 15		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats, shallow soils and coarse soils.
Chemical	R	Sites should be surveyed but will likely not need chemical site preparation. If they do, it will likely be targeted at areas with higher levels of competition as opposed to broadcast. Selective tending is probably more appropriate on these relatively low-competition sites.
Pre-harvest prescribed burning	R	Can be used to promote Pw and Pr regeneration
Post-harvest prescribed burning	CR	Use only when clearcutting and planting. Excessive damage to residuals and regeneration occurs in partial cuts.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Site prepare during good seed crop.
Planting	R	Plant usually with medium to large stock.
Seeding	CR	Appropriate site prep and tending required.
TENDING TREATMENT		
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments.
Pruning	R	If required.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 13.1, 13.2

Crop Species Objective: jack pine (Pj) with white pine and/or red pine

Silviculture System • Harvest Method		Comments
CLEARCUT		
Conventional	CR	Use only in pure Pj stands.
Seed-tree	CR	Retain desired veterans. **Section 7.2.4.3** applies. Retain at least 16 to 20 Pj trees/ha and preferably site prepare with prescribed fire.
With Standards	R	Retain desired veterans. **Section 7.2.4.3** applies.
UNIFORM SHELTERWOOD	NR	Insufficient light for development of Pj.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	R	Careful logging practices apply.
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats, shallow soils and coarse soils.
Chemical	CR	Sites should be surveyed but will likely not need chemical site preparation. If they do, it will likely be targeted at areas with higher levels of competition as opposed to broadcast. Selective tending is probably more appropriate on these relatively low-competition sites.
Pre-harvest prescribed burning	CR	May be used to meet non timber objectives where the burned stand is not harvested.
Post-harvest prescribed burning	CR	Only when clearcutting and planting or seeding, or using Pj seed trees.
Regeneration		
Natural Regeneration	CR	Site prepare as required.
Planting	R	Plant usually with small or medium stock.
Seeding	CR	Appropriate site prep and tending required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 13.1, 13.2

Crop Species Objective: jack pine (Pj) with white pine and/or red pine

TENDING TREATMENTS		Comments
Cleaning	R	If required, after seedlings are at least 3 years old..
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 14.1, 14.2 (with > 20% of stand basal area occupied by red oak)

Crop Species Objective: red oak (Or) with some Pw and Pr

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Seed-Tree	CR	Conifer component has a basal area of 4 to 12 m^2/ha. Generally requires the retention of 10 to 35 seed trees per hectare. Majority of seed trees must be oak. Conditions listed in **Section 7.2.4** apply.
With Standards	CR	Stand should have less than 4 m^2/ha basal area of Pw, Pr and Or. Conditions listed in **Section 7.2.4** apply.
SHELTERWOOD		
Or/Pw Uniform Shelterwood	R	Basal area > 12 m^2/ha of Pw, Pr, Or and Sw. Conditions listed in **Section 7.2.4** apply.
Prep Cut	R	Use to develop thrifty seed-bearers and to remove unwanted species or individuals from the canopy. Stand age usually 61 to 80 years and crown diameters are usually in the 4 to 5 metre range. Retain dominant and codominant trees of good form and vigour. **Rule of thumb**: half crown spacing of residuals.
Regeneration Cut	R	About 20 years after prep cut. Crowns should have a diameter of at least 6 to 8 metres. Crown closure after harvest should be approximately 40%.
Removal Cut	R	Follows the successful establishment of regeneration 30 cm to 1.5 m in height. Retain 30% crown closure to protect regeneration against Pw weevil.
Final Removal	R	Maintain overstory until regeneration is 6 m tall. Retain desired veterans. **Section 7.2.4.3** applies.
LOGGING METHOD		
Log Length	R	Careful skidding practices apply.
Tree Length	R	Careful skidding practices apply.
Full Tree	CR	Only in clearcut silvicultural systems. Careful logging practices apply.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 14.1, 14.2 (with > 20% of stand basal area occupied by red oak)

Crop Species Objective: red oak (Or) with some Pw and Pr

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 14.1, 14.2		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion; most sites have shallow organic mats. Do not operate machinery in wet conditions to avoid compaction and rutting on silty soils. Slopes may limit equipment choice and use.
Chemical	R	Early vegetation management beneficial to Pw, Pr, and Sw, but advance red oak regeneration should be protected.
Pre-harvest prescribed burning	R	May be used to promote Pw and Or regeneration, but will likely need a follow-up chemical or manual treatment to control non-crop vegetation.
Post-harvest prescribed burning	CR	Use only when clearcutting and planting or in shelterwood cuts if residual tree damage can be minimized.
Regeneration		
Natural Regeneration	CR	Adequate seed source must be present. Site prepare during good seed crop.
Planting	CR	Plant usually with medium or large stock.
Seeding	CR	Appropriate site prep and tending required.
TENDING TREATMENTS		
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments. Post-harvest prescribed fire may be used in clearcuts. It may also be used in shelterwood cuts if residual tree damage can be minimized.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 28.1, 28.2, 30.1, 30.2

Crop Species Objective: hemlock (He)

Silviculture System • Harvest Method		**Comments**
CLEARCUT	NR	Shade tolerant species adapted to moderate microclimatic conditions.
SHELTERWOOD		
He Uniform Shelterwood	R	Where moose or deer browsing may prevent recruitment of seedlings management strategies must be developed in the Forest Management Plan. Usually a 3-cut shelterwood, where the regeneration cut reduces crown closure to 60%. First removal cut when regeneration is between 30 cm and 1 m. Conditions listed in **Section 7.2.4** apply.
SELECTION		
Group Selection	R	Used where moose and deer populations do not prevent recruitment of seedlings. Used where a wide range of ages and sizes are desired. Group openings do not cover more than 20% of the total stand area during each cut. At least 60% of the stand must be over 10 m in height if the stand is important to deer and moose.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	NR	Results in damage to the lower stem of residuals in partial cut systems.
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	R	Target is removal of litter layer, not mineral soil exposure. Must be done while maintaining overstory cover. Seedbed must remain moist.
Chemical	R	Need to maintain shaded environment for He germination and establishment.
Pre-harvest prescribed burning	CR	Must be low intensity to avoid damaging shallow roots and thin bark of overstory. Has not been practiced operationally.
Post-harvest prescribed burning	NR	Results in open conditions unsuitable for hemlock germination and growth.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Ideally, site prepare during good seed crop.
Planting	R	Plant with medium or large stock if deer and moose browsing does not affect recruitment, otherwise consider planting red spruce.
Seeding	CR	Appropriate site prep and tending required. Seeding of He has not been widely practiced.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 28.1, 28.2, 30.1, 30.2

Crop Species Objective: hemlock (He)

TENDING TREATMENTS		Comments
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 22, 33

Northeast Site Types: 3b, 6b, 6c

Crop Species Objective: white spruce (Sw)

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	May require artificial regeneration.
Seed-Tree	R	Stand should have 4 to 12 m^2/ha basal area desired conifers. May require artificial regeneration treatments.
With Standards	R	Requires artificial regeneration treatments. Use where stands have 4 m^2/ha basal area of desired conifers or less.
SHELTERWOOD		
Sw Uniform Shelterwood	R	May be used when managing for Sw in mixtures with other species.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	CR	Only in clearcut silvicultural systems. Careful logging practices apply.
RENEWAL TREATMENTS		
Site Preparation Central Ontario ES 18.1, 18.2, 19.1, 19.2 Northeast Site Type 3b, 6b, 6c		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most a sites have shallow organic mats and coarse soils. Avoid operating machinery when soils are wet to avoid compaction on fine-textured soils typically Central Ont. “x.2” ecosites.
Chemical	R	Early vegetation management beneficial to all species on these rich ES. Consult label for hexazinone for use on coarse soils.
Pre-harvest prescribed burning	NR	Results in damage to thin-barked Sw and laddering and crown scorch may occur.
Post-harvest prescribed burning	CR	Only when clearcutting and planting.
Regeneration		
Natural Regeneration	R	Seed source must be adequate. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium or large stock.
Seeding	CR	Appropriate site prep and tending required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 22, 33

Northeast Site Types: 3b, 6b, 6c

Crop Species Objective: white spruce (Sw)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 20.1, 20.2		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats and coarse soils.
Chemical	R	Early vegetation management beneficial to all species on these rich ecosites.
Pre-harvest prescribed burning	NR	Results in damage to thin-barked Sw and laddering and crown scorch may occur.
Post-harvest prescribed burning	CR	Only when clearcutting and planting.
Regeneration		
Natural Regeneration	CR	Seed source must be adequate. Site prepare during good seed crop.
Planting	R	Plant usually with large stock.
Seeding	CR	Appropriate site prep and tending required.
Site Preparation Central Ontario ES 22, 33		
Mechanical	R	These sites may have shallow organic mats. Post-harvest scarification should not be deep or continuous.
Chemical	R	Selective or broadcast chemical treatments may be used.
Pre-harvest prescribed burning	NR	Results in damage to thin-barked Sw and laddering and crown scorch may occur.
Post-harvest prescribed burning	CR	Not recommended for organic sites.
Regeneration		
Natural Regeneration	R	Seed source must be adequate. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium stock.
Seeding	CR	Appropriate site prep and tending required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 17.2, 18.1, 18.2, 19.1, 19.2, 20.1, 20.2, 22, 33

Northeast Site Types: 3b, 6b, 6c

Crop Species Objective: white spruce (Sw)

TENDING TREATMENTS		Comments
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 30, 32

Crop Species Objective: red spruce (Sr)

Silviculture System • Harvest Method		**Comments**
CLEARCUT	NR	Shade tolerant species adapted to moderate microclimatic conditions.
SHELTERWOOD		
Sr Uniform Shelterwood	CR	Usually a 3-cut shelterwood, where the regeneration cut reduces crown closure to 60 to 70%. First removal cut when regeneration is between 30 cm and 1 m. Conditions listed in **Section 7.2.4** apply.
SELECTION		
Single-tree	R	Single tree selection is used when associated with tolerant hardwoods (***see** A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario*). May harvest during frost-free season to expose humus layer for better germination.
Group	R	Used where a wide range of ages and sizes are desired. Group openings do not cover more than 20% of the block during each cut. At least 60% of the stand must be over 10 m in height if stand is important to deer and moose.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	NR	Results in damage to the lower stem of residuals in partial cut systems.
Site Preparation Central Ontario ES 301, 30.2		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability; most sites have shallow organic mats and coarse soils.
Chemical	R	Early vegetation management beneficial to early establishment. Check hexazinone label for use on these sites.
Prescribed burning	NR	Results in damage to thin-barked Sr and laddering and crown scorch may occur.
Regeneration		
Natural Regeneration	R	Requires adequate seed source. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium or large stock.
Seeding	CR	Appropriate site prep and tending required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 30, 32

Crop Species Objective: red spruce (Sr)

Site Preparation Central Ontario ES 32		**Comments**
Mechanical	R	These sites may be dominated by organic soils. Site preparation best done in winter.
Chemical	R	Early vegetation management beneficial to early establishment.
Prescribed burning	NR	Results in damage to thin-barked Sr and laddering and crown scorch may occur.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium or large stock.
Seeding	CR	Appropriate site prep and tending required.
TENDING TREATMENTS		
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

Silvicultural Options for:

Central Ontario Ecosites: 21.1, 21.2, 22, 32, 33, 34

Northeast Site Types: 13

Northwest Ecosites: 17, 37

Crop Species Objective: cedar (Ce)

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	CR	Use where planting is planned. Open conditions create unfavourable microclimate for seed germination and early growth.
Strip and Patch	CR	Use strips 20 m wide or 100 m^2 patches. Last set of strips or patches cut using two cut shelterwood system when regeneration at least 1 m
SHELTERWOOD		
Ce Uniform Shelterwood	CR	Used where moose and deer populations do not prevent recruitment of seedlings. Usually a 3-cut shelterwood, where the regeneration cut reduces crown closure to 60%. First removal cut when regeneration is between 30 cm and 1 m.
SELECTION		
Group	R	Used where moose and deer populations do not prevent recruitment of seedlings. Used where a wide range of ages and sizes are desired. Group openings do not cover more than 20% of the total stand area during each cut. At least 60% of the stand must be over 10 m in height if the stand is important to deer and moose.
LOGGING METHOD		
Log Length	R	Careful logging practices apply.
Tree Length	R	Careful logging practices apply.
Full Tree	CR	Use only in clearcut systems. Damage to lower stem of residuals in shelterwood and selection systems. Ensure retention of coarse woody debris on site which is important for germination.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 21.1, 21.2, 22, 32, 33, 34

Northeast Site Types: 13

Northwest Ecosites: 17, 37

Crop Species Objective: cedar (Ce)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 21.1, 21.2 Northwest ES 17		
Mechanical	R	Avoid deep and/or continuous scarification to avoid erosion and reduced nutrient availability. Most sites have shallow organic mats and coarse soils. Caution should be used on organic soils in central Ontario ES 21.2. Slopes may limit the use and choice of equipment.
Chemical	R	Early vegetation management beneficial to early establishment. Check hexazinone label for use on these sites.
Pre-harvest prescribed burning	NR	Results in excessive damage to crop trees and advance growth.
Post-harvest prescribed burning	CR	Only when clearcutting and planting.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium or large stock.
Seeding	CR	Appropriate site prep and tending required.
Site Preparation Central Ontario ES 32 Northeast Site Type 13 Northwest ES 37		
Mechanical	CR	If sites are dominated by organic soils, site preparation should be done in the winter.
Chemical	R	Early vegetation management beneficial to early establishment.
Prescribed burning	NR	Results in excessive damage to crop trees and advance growth.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium stock.
Seeding	CR	Appropriate site prep and tending required.

Silvicultural Options (continued) for:

Central Ontario Ecosites: 21.1, 21.2, 22, 32, 33, 34

Northeast Site Types: 13

Northwest Ecosites: 17, 37

Crop Species Objective: cedar (Ce)

RENEWAL TREATMENTS		Comments
Site Preparation Central Ontario ES 22, 33		
Mechanical	R	Can be done pre-harvest to promote natural Ce regeneration. Should produce pit and mound topography as opposed to continuous flat surface. These site may contain shallow organic mats. Post-harvest scarification should not be deep or continuous.
Chemical	R	Selective and broadcast chemical treatments may be used.
Prescribed burning	NR	Results in excessive damage to crop trees and advance growth.
Regeneration		
Natural Regeneration	R	Adequate seed source must be present. Ideally, site prepare during good seed crop.
Planting	R	Plant usually with medium stock.
Seeding	CR	Appropriate site prep and tending required.
TENDING TREATMENTS		
Cleaning	R	If required. When considering herbicide use, see **TABLE 7.3.5** comments.
Thinning	R	If required.
Improvement cutting(s)	R	If required.

APPENDIX F

Sample Pre-harvest Prescription Forms

Sample Pre-harvest Prescription Form

An example of a pre-harvest site inspection summary form (*adapted from*: Bidwell *et al*. 1996)

Stand Description

Date	District	Twp/Basemap/FRI map#	Management Unit
Licence #	Stand #'s	Licensee #	Gross Area (ha)

Overstory

Species	(1)	(2)	(3)	(4)
Avg. DBH (cm)				
Average Ht. (m)				
Age				
Density (sph)				
Site Index				
AGS (m^2/ha)				
UGS (m^2/ha)				
Basal Area by Size Classes (m^2/ha)	P SS MS LS	P SS MS LS	P SS MS LS	P SS MS LS
Volume (m^3/ha)				
Product				

Site Description

Landform	Terrain	Slope Position	Slope %	Aspect	Other (rock, frost, etc.)

Forest Ecosystem Classification	Soil Attributes
Ecosite type	organic matter depth
	humus form
Vegetation Type	depth to restrictive layer
	moisture regime/drainage
Soil Type	depth to mottles/gley
	soil texture class

Shrub Layer			Advance Regeneration			
Species	% Cover	Height (m)	Species	Height (m)	Density (sph)	Condition

Wildfire risk (lightning, recreation, industrial) & on-site hazards

Pest management (agent, % incidence, potential risks)

Stream & lakes, VTE species (in and adjacent to site) & present downstream use

Wildlife (plant & animal), fish habitat, VTE species

Recreation/heritage (features/facilities, current use)

Mining activities (claim lines, drill sites, gridlines, aggregates)

Sample Pre-harvest Prescription Form

An example of a pre-harvest prescription form (*adapted from*: Bidwell *et al*. 1996)

Site Objectives		**Silviculture Prescription** Name of person completing the prescription: ________ Date: ________	
Harvesting Plan (Preferred)			
Harvest stand now? yes ☐ no ☐	Reasons for no harvest/deferral	Scheduling of partial cuts - selection & shelterwood (years)	
Start (season/year)	Finish (season/year)	Seasonal comments (if applicable)	
Silvicultural System		Logging Method	
Constraint(s)		Volume Expected	
Cost $		Special Conditions (reserves, etc.)	
Utilized species	Leave Species		
Rationale		Access	
Renewal Plan			
Preferred		Alternative	
Site Preparation Method		Site Preparation Method	
Year/Season		Year/Season	
Microsite objective		Microsite objective	
Constraint(s)	Cost $	Constraint(s)	Cost $
Rationale		Rationale	
Regeneration Method	Yr/Season/Spp/Stock Type	Regeneration Method	Yr/Season/Spp/Stock Type
Target densities	Cost $	Target densities	Cost $
Rationale		Rationale	
Tending Method	Yr/Season	Tending Method	Yr/Season
Objective(s)	Cost $	Objective(s)	Cost $
Constraint(s)	Cost $	Constraint(s)	Cost $
Rationale		Rationale	
Monitoring			
Survey Schedule (Type & Year)			

APPENDIX G

How to Use a Density Management Diagram

How to Use a Density Management Diagram

The Density Management Diagram is constructed using four parameters: quadratic mean diameter, stand top height, density and mean tree volume. Three of these parameters can be calculated or assessed in the field. The fourth, mean tree volume, can be read directly from the diagram. While it is recommended that the remaining three parameters be used to place the subject stand on the diagram, only two are necessary. In addition, breast-height age should be estimated so that site index (SI) of the stand can be determined.

1) Quadratic Mean Diameter (DBH_q): This is the diameter (cm) of the tree of average mean basal area. For practical purposes average DBH can be used in preference to DBH_q, but DBH_q provides more precision.

2) Stand Top Height (or Dominant Height): By definition, this is the average height (m) of the largest 100 stems (by diameter) per hectare. The average total height (m) of the dominant trees in the upper canopy of the stand can also be used as a rough estimate of stand top height.

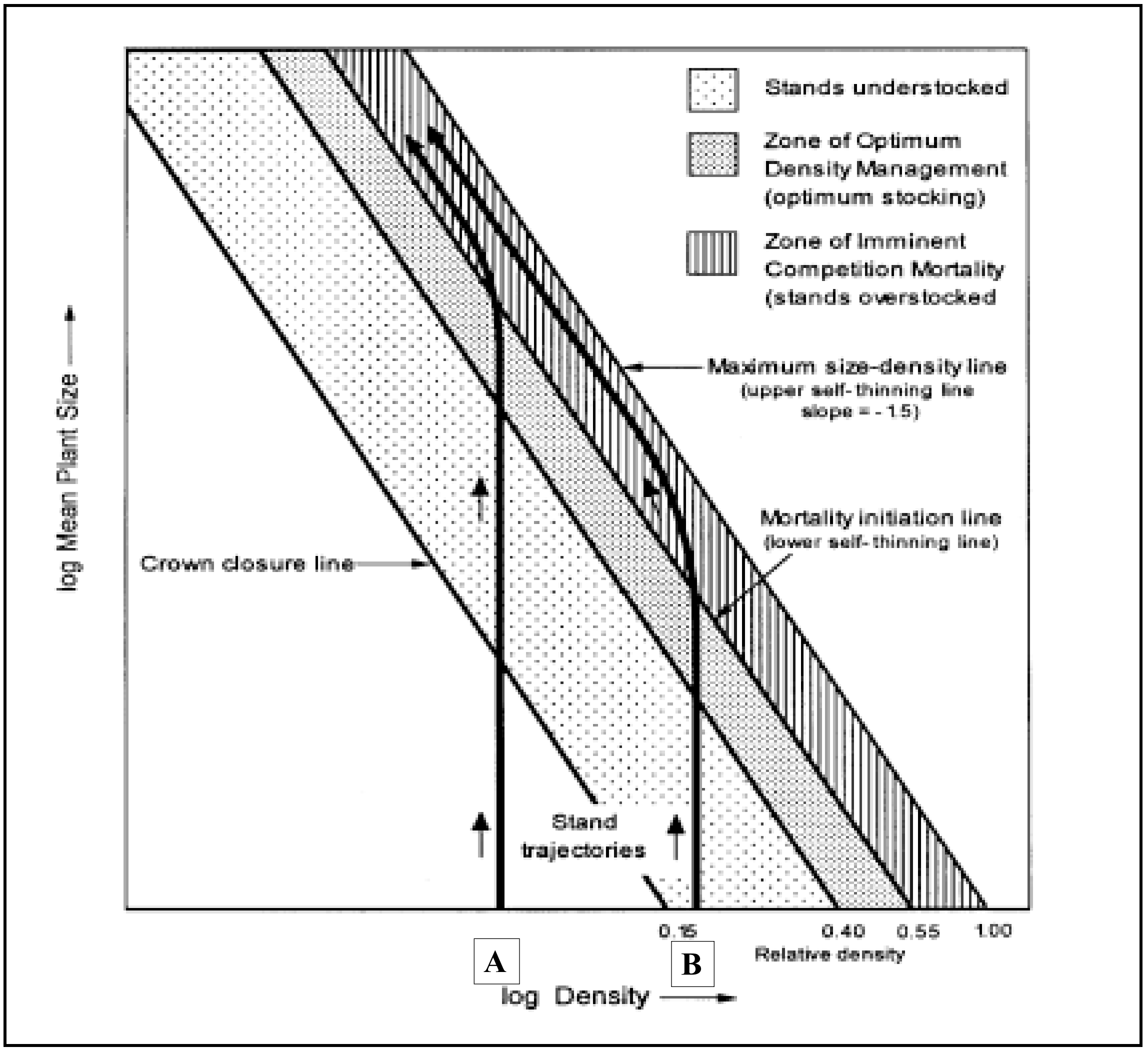
3) Density: The number of stems per hectare determined by either using fixed area plots or other methods.

4) Breast Height Age: If stand age is known then breast-height age can be estimated. If stand age is unknown it can be quickly estimated by taking an increment core (at 1.3 m) from a dominant individual (select one used for stand top height calculation) and then counting the growth rings to determine breast-height age.

The inclusion of stand quadratic mean diameter and top height isolines on the DMD permits additional stand development information to be derived, and they also provide a further check when locating stands on the DMD. By superimposing a stands' position on the diagram, silvicultural decisions can be made to ensure that a stand develops toward a desired target. Future estimates of density, quadratic mean diameter (DBH_q), and basal area (BA), plus ***approximations*** *of mean tree and total stand volume estimates* can be derived from the DMD. Site index curves provide a temporal scale that permits silvicultural intervention schedules to be developed. Top height values for a stand positioned on the DMD can be interpreted into stand age when the subject stands SI is known.

Two stand development trajectories (Stand A and B) are presented in FIGURE G1. Stand A has a lower initial density than stand B. As average tree size increases during the early stages of stand growth, density remains unchanged, and the trajectories of stand development remain vertical. As growth continues, competition between individuals increases and the rate of growth declines, then some trees will begin to die. Density-dependent mortality will occur earlier in stands (Stand B) where densities are initially higher. Once the stands transect the "mortality initiation" line, this

FIGURE G1: Example of two stand development trajectories on a Density Management Diagram



process accelerates. After stands enter the "zone of imminent competition and mortality" (ZICM) they remain there and enter a prolonged self-thinning phase. As the stand develops toward maturity there is a continual increase of mean tree size, and weaker individuals will continue to die. From the onset of the self-thinning phase the trajectory of stand development remains within the ZICM boundaries. If the stand enters the over-maturity stage and begins to break-up, then the trajectory may well drop below the lower ZICM boundary.

The utility of the diagram in planning stand thinning operations is presented in FIGURE G2. Only the even numbered DBHq and top height isolines are illustrated on the DMD for presentation purposes. Odd numbered isolines can be interpreted. Point A represents the intersection of 3 variables: 2,000 trees/ha; 16 cm; and 15 m top height. The stand is situated at the “mortality initiation” line and should be thinned before the stand enters the “zone of imminent competition and mortality" and suffers a loss of volume to mortality. The objective in the example provided is to maximize stand volume growth. To do this, the stand should be thinned to the 0.40 relative density line. To identify this point, move following the arc of the top height isolines (15 m) to the intersection of the 0.40 relative density line. This is identified as point B. The calculation of thinning values is presented on the diagram. From point B the stand will develop vertically toward the "mortality initiation" line (point C). The number of years required by the stand to reach point C from point B can be calculated using the site index curves provided. The stand in this example has a SI of 21. At point B, the stand has a breast-height age of 29 years (add 5 years for red pine total age and 6 for white pine). This is based on a top height of 15 m and a SI of 21 (refer to SI curves in FIGURE 7.5.1.3.3. At point C, the stand has a top height of 18 m and a breast-height age of 40 years (taken from the SI curves). The projected number of years that are required for the stand to grow from point B to C is 11 (40-29) years. At point C the stand requires another thinning. The same process that was used for calculating a thinning prescription is again applied. The only variation is in the estimation of point D. In this example, a decision was made to ensure that following this thinning the next harvest would occur when the stand had achieved a DBHq of 30 cm. To place point E on the DMD, simply identify the intersection of the 30 cm DBHq isoline and the "mortality initiation" line. This point is then labelled as point E. Now draw a line vertically downward until a line drawn along the arc of the 18 m top height isoline from point C is intersected. This point is labelled as point D. Calculations for point D and E are determined as described earlier. For further information and more detail refer to Smith and Woods (1997) or Archibald and Bowling (1995).

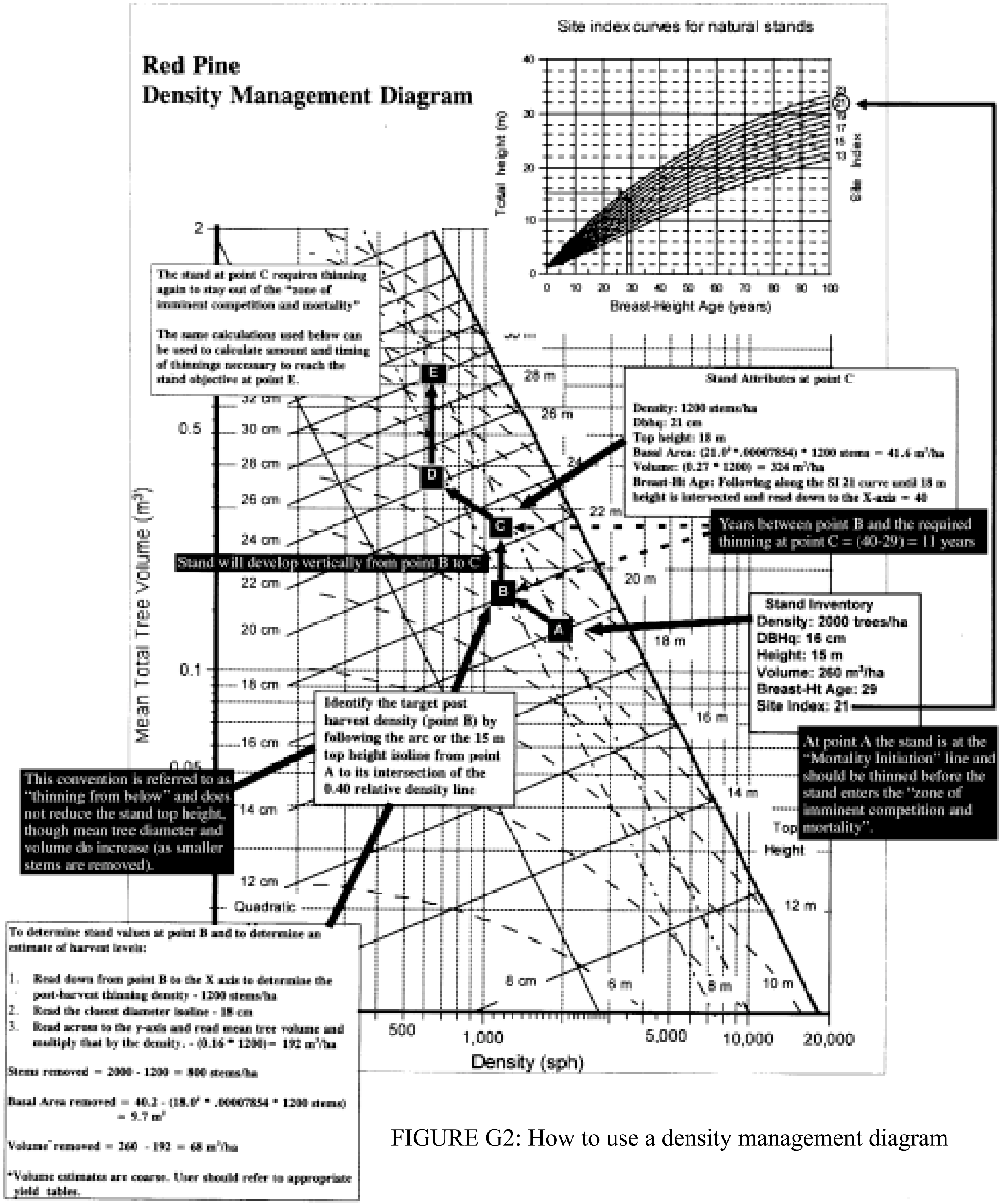


FIGURE G2: How to use a density management diagram

GLOSSARY OF TECHNICAL TERMS

A

abiotic factors. The non-living components of the environment, such as air, rocks, soil, water, peat and plant litter.

achene. A small, dry, non-splitting one-seeded fruit, with distinct seed attached to the ovary wall at only one point.

acre. An Imperial measure of land area equal to 43,560 square feet , 4046.7 square metres or 0.4 hectares.

advance growth. Young trees that have become established naturally in a forest before cutting or regeneration begin.

advanced regeneration. Trees that have become established naturally under a mature forest canopy and are capable of becoming the next crop after the mature crop is removed.

adventitious. Arising from unusual positions, as in buds on roots.

aesthetics. The study of beauty and ugliness and the judgment thereof.

afforestation. The establishment of trees on an area that has lacked forest cover for a very long time or has never been forested.

age.

- *of a tree*:
  - **breast height**: the number of annual growth rings between the bark and the pith, as counted at breast height.
  - **harvest**: the number of years required to grow from establishment to maturity.
  - **stump**: the number of annual growth rings between the bark and the pith, as counted at stump height.
  - **total**: the number of years elapsed since the germination of the seed or the budding of the sprout or root sucker.

- *of a forest, stand or forest type, the average of the trees comprising it*:
  - **harvest**: The number of years between the establishment and the final harvest of a forest crop.
  - **total**: The average total age of the trees comprising it.

age class. One of the intervals into which the range of age classes of trees in a stand are divided into for classification and use.

AGS - *acceptable growing stock*. Trees suitable for retention in the stand for at least one cutting cycle (15 to 25 years). They are trees of commercial species and of such form and quality as to be salable for sawlog products at some future date.

all-aged. Applies to a stand that contains trees of all ages.

all-aged management. A system of growing forest trees in groups where the individual trees are not the same age (theoretically, an all-aged forest has trees scattered throughout that range in age from one year to the oldest tree, whatever its age may be).

allowable cut. The volume of wood that may be harvested, under management, for a given period.

angle summation. A measure of competition that sums the subtended angle of all competing trees.

annual ring. The growth layer of one year, as viewed on the cross section of a stem, branch, or root. One year's growth consists of a layer of lighter-coloured wood (springwood) and a layer of darker-coloured wood (summerwood).

AOC - ***area of concern***. An area adjacent to an identified value that may be affected by some (or all) aspects of forest management activity.

artificial regeneration Renewal of a tree crop by direct seeding or by planting seedlings or cuttings.

aspect. The direction towards which a slope faces.

asexual. Referring to any type of reproduction which does not involve the union of sex-cells (gametes).

audit. A formal examination of an organization's or individual's performance.

azimuth. The horizontal angle or bearing of a point measured from the true (astronomic) north. Used to refer to a compass on which the movable dial (used to read direction) is numbered in 360. ***see*** *bearing* and *compass*.

B

barren and scattered - ***B&S***. Productive forest land which, because of natural or artificial disturbance, contains only scattered trees (stocking below 0.25) or no trees at all with either shrub cover or bare soil, but no significant amount of regeneration. Treatment is required to restore such areas to productivity.

basal area.

- *of a tree*:
  - the cross-sectional area of the bole of a tree, 1.3 metres above the ground. Basal area = diameter of tree (cm) squared, times 0.00007854. (Expressed in square metres).
- *of a stand of trees*:
  - the sum of all the individual tree basal areas for a given land area. Commonly expressed as square metres per hectare.

bearing. A direction on the ground or on a map defined by the angle measured from some reference direction: this may be true (geographic) north, magnetic north, or grid north.

bear's nest. An abiotic defect in mast trees formed when animals break off branches in order to reach mast. Host trees are weakened due to loss of crown.

berry. A pulpy, non-splitting fruit developed from a single pistil and containing one or more seeds.

biodiversity - ***biological diversity***. The variety and variability (in time and space) among living organisms and the ecological complexes in which they occur.

biomass. The dry weight of all organic matter in a given ecosystem. It also refers to plant material that can be burned as fuel.

biosphere. That part of the earth and atmosphere capable of supporting living organisms.

biota. All living organisms of an area, taken collectively.

blowdown (**windthrow**). Uprooting by the wind. Also refers to a tree or trees so uprooted.

board foot. A volume measure of lumber, being one foot wide, one foot long and one inch thick.

bole. The main trunk of a tree.

bolts (**boltwood**). Short material to go into turned wood products.

breast height. The standard height, 1.3 m above ground level, at which diameter of a standing tree is measured.

broadleaf. ***see*** *hardwood.*

browse. Small bushes, sprouts, herbaceous plants, small trees, etc. that wildlife feed on.

brush. Commonly refers to undesirable shrubs and other low-lying vegetation.

bucking. Cutting a felled tree into specified log lengths for yarding and hauling; also, making any bucking cut on logs.

buffer. A zone or strip of land that shields one area from another. Commonly used along streams or as visual barriers.

burl. An abnormal growth on a tree stem, with wood tissue growing in an irregular pattern. Usually circular in shape, these growths are widely sought for their interesting grain pattern.

butt. The base of a tree or log.

C

caliper. An instrument used to measure diameters of trees or logs. It consists of two parallel arms at right angles to a graduated rule, with one arm that slides along the rule.

calyx. The outermost group of floral parts.

cambium. A layer of cells between the woody part of the tree and the bark. Division of these cells results in diameter growth of the tree through formation of wood cells (xylem) and inner bark (phloem).

canker. Dead area of a branch or stem caused by fungal or bacterial attack.

canopy. A collective term for the layer formed by the crowns of the taller trees in a forest.

canopy closure. The progressive reduction of space between crowns as they spread laterally, increasing canopy cover.

canopy gap. A hole in the forest canopy that allows light penetration to the forest floor. Can be formed by naturally falling trees, standing dead trees and logging practices.

capsule. A dry, usually many seeded fruit that splits at maturity to release its seeds.

caryopsis. A simple, dry, one-sided, non-splitting fruit with seed firmly attached to the entire ovary wall.

catface. A scar on the surface of a log, generally elliptical in shape, resulting from wounds that have not healed over; also a scar near the base of a tree.

catkin. A scaly spike bearing inconspicuous and usually unisexual flowers.

cavity. An unfilled space within a mass, a hollowed out space. In forestry and wildlife there are several categories of cavity trees, each with their own importance in the ecosystem:

- **Pileated woodpecker roost cavities**: First priority for retention are living or standing dead trees with cavities used by pileated woodpeckers for roosting. These are usually large (40+ cm DBH) diameter trees that are hollow and have at least two excavated entrance holes. These holes are somewhat oval, about 7.5 to 10 cm wide and 10 to 12.5 cm high. Holes are symmetrically oval, smooth edged and deep.
- **Pileated woodpecker nest cavities**: Second priority for retention are living trees with cavities used by pileated woodpeckers for nesting. These are usually large (40+ cm DBH) diameter trees in which pileated woodpeckers have excavated one or more nest chambers and associated entrance holes. Nest and roost trees can be distinguished by the number of entrance holes and tree condition. Roost trees may have 2 to 10+ entrance holes and entrance holes may be less than 1 metre apart. Condition is probably the best clue to separate nest and roost trees. Pileated woodpeckers excavate nest cavities in trees with white spongy heart rot (not trees with existing hollows). Roost cavities are in hollow trees (look for seams, barreling, etc. to indicate hollowness).
- **Other woodpecker nest cavities or natural nest or maternal den cavities**: The third priority for retention are living trees with cavities excavated by other woodpeckers (e.g. yellow-bellied sapsucker, hairy woodpecker, northern flicker) for nesting or cavities suitable for nesting or denning (by secondary cavity users) that formed from natural decay processes.
- **Escape cavity**: The fourth priority for retention are living trees with natural cavities that provide temporary shelter, escape from predators, food-caching sites, or resting/loafing/roosting sites. They are not ideal for nests or dens because of location, size, entrance hole size, or orientation.
- **Feeding cavity**: The fifth priority for retention are living trees with feeding excavations created by woodpeckers in search of food. They are generally rectangular, semi-circular, or irregular. Holes do not typically enlarge into chambers suitable for nesting or escape. Edges and surfaces tend to be rough.
- **Potential cavity tree**: Trees with potential to attract excavators or develop natural cavities. Typically they have evidence of advanced heart rot. These living trees are retained when situations arise in areas that do not have at least 6 existing cavities per hectare left after tree marking.

check. A lengthwise separation of the wood, which usually extends across the rings of annual growth, commonly resulting from stresses set up in wood during drying.

cleaning. Elimination or suppression of competing vegetation from stands not past the sapling stage; specifically, removal of:

- weeds, climbers, or sod-forming grasses, as in plantations; or
- trees of similar age or of less desirable species or form than the crop trees which they are, or may soon be, overtopping.

clearcut. An area on which the entire timber stand has been harvested. ***see*** *reproduction methods*.

clear-length. Branch-free length of the bole.

climax vegetation. The final stage of natural plant succession, in which the plant composition remains relatively stable.

clinometer. An instrument for measuring vertical angles or slopes.

clone. All plants reproduced asexually from a common ancestor and having identical genotypes. (genetically identical to the parent plant) (e.g. from cuttings or suckers).

coarse woody debris (**CWD**). Sound and rotting logs and stumps that provide habitat for plants, animals and insects and a source of nutrients for soil development.

codominant trees. Trees with crowns forming the general level of the crown cover and receiving full light from above, but comparatively little from the sides; usually with medium size crowns. ***see*** *crown class*.

commercial thinning. Removing trees from a developing young stand, so that remaining trees will have more growing space; dead and dying trees will be salvaged; and the operation will make a net profit.

community. An integrated group of species inhabiting a given area and influencing one another's distribution, abundance and evolution.

compass. An instrument used to determine the direction of magnetic north. ***see*** *bearing* and *azimuth*.

competition. The general struggle for existence within a trophic level in which the living organisms compete for a limited supply of the necessities of life.

composition. The representation of tree species in a forest stand, expressed quantitatively as per cent by volume or basal area of each species.

cone. The male or female reproductive organs of conifers.

conifer. A tree belonging to the order Coniferae, usually evergreen with cones, needle-shaped leaves and producing wood known commercially as 'softwood.'

conk. A hard, spore-bearing structure of a wood-destroying fungus that projects beyond the bark of a tree.

conservation. In forestry, the wise use of natural renewable resources. A key idea for understanding 'conservation' is 'use' by people.

conventional ground skidding. Any combination of rubber-tired or tracked skidding equipment.

coppice. A shoot (sprout) originating from a stump.

coppice forest. A forest originating from sprouts or suckers. A 'low' forest.

cord. 128 cubic feet of stacked roundwood (whole or split, with or without bark) containing wood and airspace, with all the pieces of similar length and lined up on approximately the same direction. i.e. a pile of firewood 4'x 4' x 8'.

corridor. A band of vegetation, usually older forest, which serves to connect distinct patches on the landscape. Corridors provide connectivity which permit the movement of plant and animal species between what would otherwise be isolated patches.

cover. Vegetation or other material providing protection. Plants or objects used by wild animals for nesting, rearing of young, resting, escape from predators, or protection from adverse environmental conditions.

critical wildlife habitat. Part or all of a specific place occupied by a wildlife species or a population of such species and recognized as being essential for the maintenance of the population.

crook. A defect in logs and poles or pilings, consisting of an abrupt bend. Also refers to edgewise warp in a piece of lumber.

crop tree. A tree selected in a young stand, to be retained until final harvest.

crotch. The fork of a tree or branch.

crown. The branches and foliage of a tree.
crown class. A designation of trees in a forest with crowns of similar development and occupying similar positions in the crown cover. Differentiation into crown classes applies to even-aged stands and within small even-aged groups in which trees in an uneven-aged stand are often arranged. Five crown

classes are commonly recognized: dominant, codominant, intermediate, overtopped (suppressed), and wolf trees.

crown closure. The time at which the available crown space has become fully occupied.

crown cover. The canopy of green leaves and branches formed by the crowns of all trees in a forest. Generally expressed as a per cent of total area.

crown density. The compactness of the crown cover of the forest; depends on the distance apart and the compactness of the individual crowns. A loose term combining the meanings of 'crown closure' and 'shade density.'

cruising. Measuring standing trees to determine the volume of wood on a given tract of land. Used for harvesting, purchasing and general management.

cubic metre. A volume measure, one metre by one metre by one metre.

cull. A tree or log of merchantable size rendered unmerchantable because of poor form, large limbs, rot, or other defects.

cull tree. A live tree of merchantable size but unmerchantable because of defects or decay.

cutting area. A portion of woodland on which timber is being cut or will be cut.

cutting cycle. The planned interval between major harvesting operations in the same stand. A 20-year cutting cycle indicates a harvest is done once every 20 years.

D

darkface basal wound. Usually a ground-contact wound that is grey-black in appearance, moist, with a somewhat spongy surface.

DBH - *diameter at breast height*. The diameter of a tree outside of the bark at roughly breast height. Normally measured 1.3 metres off the ground on the uphill side of the tree. It is easier to measure at this height and many trees have large swells in the stem below this point that could increase errors in computing tree volumes.

deciduous. Term applied to trees (commonly broad-leaved trees) that drop all their leaves sometime during the year.

declination (**magnetic**). The angle between true (geographic) north and magnetic north (direction of the compass needle). Declination varies from place to place and can be 'set' on a compass for a particular location.

decline causing defects. Mechanical or pathological defects that may cause decline or cause the tree to be of high risk. These defects will also cause the decline of the products which may be recovered from a tree or severely limit the potential of a tree to produce anything better than low-value products.

defect. Any irregularity or imperfection in a tree, log, piece, product, or lumber that reduces the volume of sound wood or lowers its durability, strength, or utility value.

defect class. A system of categorizing tree defects by severity of degradation of the tree and/or the merchantable portion of the tree over time:

- **major defect**: The tree will degrade rapidly.
- **moderate defect**: The tree will degrade slowly.
- **minor defect**: The tree will maintain quality over cutting cycle period.

defoliator. An agent that damages trees by destroying leaves or needles.

den tree. A tree having a hollow or cavity used by animals for refuge or hibernation.

dendrology. The identification and systematic classification of trees and shrubs.

densiometer. An instrument used to estimate a forest overstory density, crown closure.
diameter. The longest distance at right angles, across any circle or cylinder. In standing trees, estimate diameter by dividing the circumference (length of a line taken completely around the outside of a tree) by 3.14159.

diameter class. One of the intervals into which the range of diameters of trees in a forest is divided for purposes of classification and use. Generally this is done in 2 cm, even increments (40 cm class would contain trees from 39.1 to 41.0 cm)

diameter limit. The smallest (occasionally the largest), size to which trees or logs are to be measured, cut, or used. The points to which the limit usually refer are stump, breast height, or top.

diameter-limit cutting. A system of selection harvest based on cutting all trees in the stand over a specified diameter. This eliminates marking individual trees. This is not a recognized silvicultural system in Ontario.

diameter tape. A graduated tape based on the relationship of circumference to diameter, which provides a direct measure of tree diameter when stretched around the outside of the tree.

dib - ***diameter inside bark***. The diameter of a tree or log excluding the bark thickness.

dioecious. Producing male and female reproductive organs on separate plants. Each plant is either male or female.

disease. Harmful deviation from normal functioning of physiological processes, generally pathogenic or environmental in origin.

dob - ***diameter outside bark***. The diameter of a tree or log including the bark thickness.

dominant trees. Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side; larger than the average trees in the stand, with crowns well developed, possibly somewhat crowded on the sides. ***see*** *crown class*.

dormancy.

- A biological process in which a plant ceases most growth activities and simply maintains existing tissue. Caused by periods of moisture and/or temperature stress.
- A state of reduced activity in seeds that prevents germination under favourable environmental conditions.

drumlin. Elongated oval or 'whale-back' ridge of deep molded glacial till formed during ice advance and with long axis parallel to ice movement.

drupe. A fleshy, usually one-seeded fruit whose seed is completely enclosed in a hard, bony endocarp.

dry rot. A decay of the "brown rot" type, caused by specialized fungi capable of conducting moisture from an available source and extending their attack to wood previously too dry to decay. Found chiefly in buildings. The term is open to the misinterpretation that wood will rot when dry, which is not true.

duff. Forest litter and other organic debris in various stages of decomposition on top of the mineral soil; typical of coniferous forests in cool climates, where rate of decomposition is slow and where litter accumulation exceeds decay.

E

ecology. The science that deals with the interaction of plants and animals with their environment.

ecosystem. A functional unit consisting of all the living organisms (plants, animals and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size—a log, pond, field, forest, or the earth's biosphere—but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation, for example, forest ecosystem, old-growth ecosystem, or wetland ecosystem.

ecosystem management. The use of an ecological approach to achieve productive resource management by blending social, physical, economic and biological needs and values to provide healthy ecosystems.

edge. The transitional zone where one cover type ends and another begins.

endangered species. A species of native fish, wildlife, or plants found to be threatened by extinction because its habitat is threatened with destruction, drastic modification, or severe curtailment, or because of over-exploitation, disease, predation, or other factors its survival requires assistance.

endocarp. The inner wall layer of a ripened ovary.

environment. All elements, living and inanimate, that affect a living organism.

epicormic sprout. A branch rising spontaneously from an adventitious or dormant bud on the stem or branch of a woody plant.

epidemic. Widespread insect or disease incidence beyond normal proportions; usually accompanied by excessive damage.

even-aged. The conditions of a forest or stand composed of trees having no, or relatively small, differences in age, although differences of as much as 30 per cent are admissible in rotations greater than 100 years of age.

even-aged management. The application of a combination of actions that results in the creation of stands in which trees of essentially the same age grow together. The difference in age between trees forming the main canopy level of a stand usually does not exceed 20 per cent of the age of the stand at maturity. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for regeneration and is harvested. Cutting methods producing even-aged stands are clearcut, shelterwood, or seed-tree.

even-flow harvest. A harvesting scheme designed to extract exactly the same volume of wood fibre each period.

exotic. Not native; foreign.

F

featured species. A species for which habitat management is conducted explicitly.

felling and bucking. The process of cutting down standing timber and then cutting it into specific lengths for yarding and hauling.

fertilization. The addition of fertilizer to promote tree growth on sites deficient in one or more soil nutrients. Also used to improve the vigor of crop trees following juvenile spacing or commercial thinning.

final cutting. The removal of seed or shelter trees after regeneration has been effected, or removal of the entire crop of mature trees under a clear cut silvicultural system.

fire scar. An injury or wound in the bole of a tree caused or accentuated by fire.

fixed area plot sampling method. A controlled cruise method where small plots of a fixed size are used to sample a portion of a forest area to obtain information (such as tree volume) that can be used to describe the whole area.

fluxing. An abnormal discharge from a crack or seam.

forb. A small herbaceous plant, unlike grass.

forest. A plant community predominantly of trees and other woody vegetation, growing more or less closely together; An area managed for the production of timber and other forest products, or maintained under woody vegetation for such indirect benefits as protection of site or for recreation.

forest management. The application of business methods and technical forest principles to the management of forest property.

forest protection. The activities connected with the prevention and control of damage to forests from fire, insects, disease and other injurious and destructive sources.

forest site. A land unit characterized by climate, soil and topographic features that control forest type and growth.

forest survey. An inventory of forest land to determine size, condition, timber volume and species, for specific purposes or as a basis for forest policies and programs. Also refers to carefully measuring and marking property boundaries.

forest type. A descriptive term used to group stands of similar character in composition and development, to differentiate them from other groups of stands.

forest utilization. That branch of forestry concerned with the operation of harvesting, processing and marketing the forest crop and other forest resources.

forestation. The establishment of forest naturally or artificially on areas where it has been absent or insufficient.

forester. A person who has been professionally educated in forestry at a university.

forestry. The science, art and practice of managing and using for human benefit the natural resources that occur on and in association with forest lands.

form. The shape of a log or tree.

form class. A measure of bole taper derived by dividing diameter inside bark at a given height (usually 5.2 or 10.4 metres) by DBH. These values are often required to use tree-volume tables.

fragmentation. The process of transforming large continuous forest patches into one or more smaller patches surrounded by disturbed areas. This occurs naturally through such agents as fire, landslides, windthrow and insect attack. In managed forests timber harvesting and related activities have been the dominant disturbance agents.

free-to-grow. A condition in which a forest is considered established based on a minimum stocking standard, a minimum height and freedom from competition that could impede growth.

frost crack. Longitudinal crack on the outside of a tree, caused by extreme cold. Especially common on thin-barked species.

fruiting body. ***see*** *conk*.

fuelwood. Trees used for the production of firewood logs or other wood fuel.

full-tree harvesting. A tree harvesting process that includes removing the trunk, branches and in some instances the roots from a forested site. In Canada this process is used to control root diseases.

fungus. A plant without chlorophyll that derives its nourishment from the organic matter of other plants.

G

gall. A pronounced localized swelling of greatly modified structure that occurs on plants from irritation by a disease or insect.

gallery. A passage or burrow, excavated by an insect under bark or in wood for feeding or egg-laying purposes.

gap phase replacement. Refers to the dynamic ongoing process in undisturbed tolerant hardwood stands in which canopy gaps are continually created by the death or destruction of mature trees. The gap becomes the site of increased regeneration and survival and eventually is occupied by trees reaching into the upper canopy.

genetic diversity. Variation among and within species that is attributable to differences in hereditary material.

genetically improved seed and/or vegetative propagules. Seed or propagule that originate from a tree breeding program and that have been specifically designed to improve some attribute of seeds, seedlings, or vegetative propagules selection.

genotype. The entire genetic constitution, or the sum total of genes of an organism, in contrast to the phenotype.

geographic information system (**GIS**). A computer system designed to allow users to collect, manage and analyze large volumes of spatially referenced information and associated attribute data.

germination. The resumption of active growth in the embryo of a seed, as demonstrated by the protrusion of a radicle (embryonic root axis).

girdle. To encircle the stem of a living tree with cuts that completely sever bark and cambium and often are carried well into the outer sapwood, done to kill the tree by preventing the passage of carbohydrates to the roots. Also refers to same process caused by animals, such as mice or beavers.
glaze damage. Damage to tree caused by ice or frost.

grade.
- A system of classifying lumber or logs according to quality.
- The steepness of a forest road.

grain. A small hard seed or seed-like fruit, as for any of the cereals.

gross total volume. Volume of the main stem of the tree including stump and top. Volume of the stand including all trees.

group selection. Modification of the selection system in which trees are removed in small groups rather than as individuals.

growing stock. The sum, by number or volume, of all the trees in a forest or a specified part of it.

growth. The increase in diameter, basal area, height or volume of individual trees or groups of trees during a given period.

growth rate. With reference to wood, the rate at which wood has been added to the tree at any particular point, usually expressed in the number of annual rings per centimetre. May also be stated as "annual leader growth."

H

habitat. The environment in which the plant or animal lives.

hardwood.

- Generally, one of the botanical group of trees that have broad leaves, in contrast to the needle-bearing conifers.
- Wood produced by broad-leaved trees, regardless of texture or density.

harvest. Extraction of some type of product from the forest. Generally associated with a cutting.

heart rot. A decay characteristically confined to the heartwood. It usually originates in the living tree.

heartwood. The inner core of a woody stem, wholly composed of non-living cells and usually differentiated from the outer enveloping layer (sapwood) by its darker colour.

heavy hardwood. A general term referring to trees of high specific gravity.

hectare. An area measure of 10,000 square metres. Basic unit of land area.

herb. A non-woody flowering plant.

high grading. The removal from the stand of only the best trees, often resulting in a poor-quality residual stand.

hip. The fleshy, false fruit of the rose.

humus. The plant and animal residues of the soil (litter excluded) that have decomposed to the point where their origin is no longer recognizable.

hypsometer. An instrument used to measure the heights of trees, employing geometric or trigonometric principles.

I

ice damage. Breakage of tops and branches and stripping of branches and needles by an ice storm.

immature. Trees or stands that have grown past the regeneration stage, but are not yet mature.

improvement cutting. The elimination or suppression of less valuable trees in favour of more valuable trees, typically in a mixed, uneven-aged forest.

increment. An increase in the diameter, basal area, height, volume, quality, or value of individual trees or stands over time.

- **Current Annual Increment** (**CAI**): Growth increment in a given year of the diameter, basal area, height or volume for a given tree or group of trees.
- **Mean Annual Increment** (**MAI**): The average annual increment for the total age of the diameter, basal area, height or volume for a given tree or group of trees.

increment borer. A tool used to extract a core of wood from a tree, allowing study of the radial growth of a tree without felling it.

increment core. That part of the cross section of a tree extracted by an increment borer. Used to determine tree age and growth.

indicator species. Species of plants used to predict site quality and characteristics.

infection courts. Paths by which insects and disease can enter a tree, leading to defect and decay (e.g. wounds)

inflorescence. A floral axis with its appendages.

intermediate trees. Trees shorter than those in the dominant or codominant classes, but with crowns either below or extending into the crown cover formed by codominant and dominant trees; receiving a little direct light from above, but none from the sides; usually with small crowns, considerably crowded on the sides. ***see*** *crown class*.

intolerance. Trees unable to survive or grow satisfactorily under specific conditions, most commonly used with respect to their sensitivity to shade but also to conditions such as wind, drought, salt and flooding.

IRM - *integrated resource management*. The identification and consideration of all resource values, including social, economic and environmental needs, in land use and development decision making. It focuses on resource use and land use and management and is based on a good knowledge of ecological systems, the capability of the land and the mixture of possible benefits.

ITAWCRUZ - *Integrated Timber and Wildlife Operational Cruise*. A pre-harvest quality-class cruising system.

J

juvenile spacing. A silvicultural treatment to reduce the number of trees in young stands, often carried out before the stems removed are large enough to be used or sold as a forest product. Prevents stagnation and improves growing conditions for the remaining crop trees so that at final harvest the end-product quality and value is increased. Also called pre-commercial thinning.

K

keystone species. A species that plays an important ecological role in determining the overall structure and dynamic relationships within a biotic community. A keystone species presence is essential to the integrity and stability of a particular ecosystem.

knot. That part of a branch that has been incorporated into the main stem.

L

landing. The area where logs are collected for loading for transport to a mill.

landscape. All the natural features, such as fields, hills, forests and water that distinguish one part of the Earth's surface from another part; usually that portion of land or territory which the eye can comprehend in a single view, including all of its natural characteristics.

layering. The rooting of an undetached branch, lying on or partially buried in the soil or other forest floor media, that is capable of independent growth after separation from the parent plant.

leader. The growing top (terminal shoot) of a tree. The distance up the main stem of the tree between each whorl of branches generally represents one year of height growth.

leave tree. Tree left in or just outside a harvest zone (often otherwise a clearcut) to re-seed the area. This is nature's method of reforestation; but it is often slower and it does not have the more assured results of direct seeding or planting. May also refer to trees left after a thinning.

liberation cut. The release of young stands, not past the sapling stage, from the competition of distinctly older, over-topping trees. The trees that are cut are those left standing when the previous stand was harvested or, for other reasons, present long before the natural or artificial establishment of the young trees. Liberation cuttings are somewhat like the removal cutting of the seed-tree and shelterwood methods of regeneration in which overstory trees are removed after the new crop is established. The trees removed in liberation were not, however, ones that had been left intentionally to provide seed, shelter, or additional growth.

litter. The uppermost layer of the soil, made up of freshly fallen or slightly decomposed organic materials.

live crown ratio (**LCR**). The length of the crown as a ratio of the total height of the tree, usually expressed as a per cent.

log.

- To cut and deliver logs.
- A tree segment suitable for lumber and other products.

logger. A person who is engaged in a logging operation; locally, one who moves logs to landings or skidways.

log rule. A table showing the estimated or calculated amount of lumber that can be sawn from logs of given length and diameter.

log scale. The lumber content of a log as determined by a log rule.

lopping. Chopping branches, tops and small trees after felling into lengths such that the resultant slash will lie close to the ground.

M

management plan. A written plan for the organized handling and operation of a forest property. It usually includes data and prescribes measures designed to provide optimum use of forest resources according to the landowner's objectives.

marking timber. Selecting and indicating, usually by a paint mark, trees to be cut or retained in a harvesting or tending operation.

mast. The fruit and nuts of trees and woody shrubs used as a food source by wildlife.

mast trees. Trees supporting mast production, e.g. oak, beech, cherry.

maturity. For a given species or stand, the approximate age or condition beyond which the growth rate declines or decay begins to assume economic importance.

mean annual increment (**MAI**). The average annual increase in volume of individual trees or stands up to the specified point in time. The MAI changes with different growth phases in a tree's life, being highest in the middle years and then slowly decreasing with age. The point at which the MAI peaks is commonly used to identify the biological maturity of the stand and its readiness for harvesting.

mechanical site preparation. Any activity that involves the use of mechanical machinery to prepare a site for reforestation.

mensuration. The science dealing with the measurement of the volume, growth and development of individual trees and stands, and the determination of the various products obtainable from them.

merchantable. That part of a tree that can be manufactured into a salable product.

merchantable height. The length of the tree stem from the top of the stump to the top of the last merchantable section. Usually expressed in metres or number of logs.

merchantable length. Length of the tree from which could be produced a merchantable product under given economic conditions.

merchantable timber. A tree or stand of trees that may be converted into salable products.

merchantable volume. The amount of wood in a single tree or forest stand that is considered salable.

metre. Measure of length equal to 100 centimetres.

metric chain. A 20 metre measure.

microclimate. Generally the climate of small areas, especially insofar as this differs significantly from the general climate of the region. Stands often create microclimates.

microsite. A portion of a site that is uniform in microtopography and surface soil materials. It can range in size from less than 1 m^2 to occasionally over 5 m^2. Microsites are dynamic in that their characteristics are ever-changing, imperceptibly or suddenly.

mineral soil. Soil consisting predominately of, and having its properties determined by, inorganic matter. Usually contains less than 20 per cent organic matter.

monoecious. Bearing separate male and female flowers on the same tree.

moosehorn. ***see*** *densiometer.*

mortality. Death of forest trees as a result of competition, disease, insect damage, drought, wind, fire and other factors.

multiple-use. A system of resource use where the resources in a given land unit serve more than one user. Multiple use can be effected in three ways:

- different uses of adjacent sub-areas which together form a composite multiple use area;
- the alternation in time of different uses on the same areas; and
- more than one use of an area at one time.

In multiple use planning, where differing resource uses are conducted at the same time on the same area and conflicts between users will occur, one resource is determined to be the dominant use and all other secondary uses are integrated only in-so-far as they are compatible with the first. Often multiple use planning sacrifices the production of the individual resources in favour of the over-all mix of resource uses that brings the greatest social and economic benefits.

mycorrhiza. A rootlet of a higher plant modified through integral association with a fungus to form a constant structure which differs from either component but is attached to the root system and functions somewhat as a rootlet. It is usually considered to be beneficial to the associated plant.

N

natural regeneration. The renewal of a forest stand by natural seeding, sprouting, suckering, or layering seeds may be deposited by wind, birds or mammals.

natural thinning. Death of trees in a stand as a result of competition.

needle cast. Premature browning and dropping of needles caused by a fungus.

NMV - ***net merchantable volume***. The result of removing volume associated with stain or decay from the gross merchantable volume or trees or cut timber.

non-forest land. Land withdrawn from timber production for at least the next rotation.

non-productive forest land. Land within a forested area that is incapable of commercial timber production owing to very low productivity.

NSR - ***not satisfactorily regenerated***. Productive forest land not stocked to a specified standard or that has not attained free-to-grow status.

nurse tree (**crop tree**). A tree or crop of trees, shrubs, or other plants that foster another, generally a more important, tree or crop.

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

nutlet. A small nut.

O

old growth. A forest that has never been changed by management or harvesting. This term is misapplied by many to describe any forest that appears to be old. Individual trees in this type of forest are usually over 200 years old and there are large standing and fallen dead trees throughout the stand.

operation. Used interchangeably for logging jobs, harvesting, cutting, milling, etc. An all-inclusive term for harvesting and hauling out the forest products.

organic litter. The layer of decomposing leaves, bark, twigs and other organic debris that lies on the forest floor.

organic soil. Soil containing a high proportion (greater than 20 or 30 per cent) of organic matter.

overmaturity. That period in the life cycle of trees and stands when growth or value is declining.

overstocked. A condition of the stand or forest, indicating more trees than desired, normal, or full stocking would require.

overstory. That portion of the trees in a stand forming the upper crown cover.

overtopped tree. Trees with crowns entirely below the general level of the overstory cover, receiving no direct light either from above or from the sides. Also known as suppressed. ***see*** *crown class*.

P

partial cutting. Refers generically to stand entries, under any of the several silvicultural systems, to cut selected trees and leave desirable trees for various stand objectives. Partial cutting includes harvest methods used for seed tree, shelterwood, selection and clearcutting with reserves systems.

patch cutting. A silvicultural system that creates openings less than 1 hectare in size and is designed to manage each opening as a distinct even-aged opening.

pathological rotation age. The maximum rotation age through which a stand of trees may be grown without significant volume loss from disease. The stand age at which annual volume loss from disease equals annual volume increment.

pathology (**forest**). The science that pertains to diseases of forest trees or stands and to the deterioration of forest products by organisms.

per cent grade.

- The vertical rise of land in 100 horizontal units. A 16 per cent grade means that in 100 metres horizontal, the elevation has changed 16 metres.
- Amount of forest volume found to be in a given log grade.

perfect. Having both functional male and female reproductive organs.

pest. A plant, animal, or thing that is troublesome or annoying (from a human value perspective).

phenology. Study of the relations between seasonal climatic changes and periodic biological phenomena, such as the flowering and fruiting of plants.

phloem. The tissues of the inner bark, characterized by the presence of sieve tubes and serving for the transport of elaborated foodstuffs.

photosynthesis. The conversion by green plants of light, water and air into food energy.

physiographic system. A system that comprises the inorganic portion of the environment outside of the works of man.

pioneer (**botanical**). A plant capable of invading bare sites (that is, a newly exposed soil surface) and persisting there until supplanted by successor species. A species planted to prepare a site for such successor species and therefore, a nurse crop.

plantation. An artificially reforested area established by planting or by direct seeding.

plot. A carefully measured area laid out for experimentation or of mensuration; may be permanent or temporary.

point sampling. A method of selecting trees for measurements and of estimating stand basal area at a sample location or point sample. Also called plotless cruising, angle count method. A 360 degree sweep is made with an angle gauge about a fixed point and the stems with breast height diameters appearing larger than the fixed angle subtended by the angle gauge are included in the sample.

pole.

- A young tree between 10 and 25 cm in DBH.
- A log cut for the manufacture of utility poles (usually trees larger than 30 cm DBH).

polewood. Trees with a DBH between 10 and 25 centimetres.

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

pre-commercial thinning. Removal of some of the trees in a young stand to reduce competition for water, nutrients and light and to accelerate commercial growth on remaining trees. Trees thinned from these stands have no commercial value.

pre-harvest silviculture assessment (**survey**). The survey carried out on a stand prior to logging to collect specific information on the silvicultural conditions such as planting survival, free-growing status, stocking, etc.

pre-harvest silviculture prescription (**PHSP**). A document that applies site-specific field data and develops forest management prescriptions for areas in advance of logging.

preparatory cutting. The removal of trees near the end of a rotation, which permanently opens the canopy and enable the crowns of seed bearers to enlarge, to improve conditions for seed production and natural regeneration. Typically done in the shelterwood system.

prescribed burning. The knowledgeable application of fire to a specific unit of land to meet predetermined resource management objectives.

prescription. A course of management action prescribed for a particular area after specific assessments and evaluations have been made.

preservation. To maintain in a natural state; human impact on the biological system is minimized. Commonly refers to wilderness area management.

primary excavator (**tree cavity**). Animals that excavate their own cavities.

primitive area. An area of forest land that is left unaffected by human activities. These areas are in essence wilderness, but they are created by administrative regulation.

prism. A wedge-shaped piece of clear or amber-coloured glass that is used to select trees for timber sampling or to estimate basal area.

production forest. All productive forest land managed primarily to growing timber for industry unless otherwise reassigned.

productive forest land. All forest areas capable of growing commercial trees and not withdrawn from such use.

pruning. The removal of live or dead branches from standing trees, usually the lower branches of young trees and the removal of multiple leaders in plantation trees, for the improvement of the tree or its timber; the cutting away of superfluous growth, including roots, from any plant to improve its development. ***see*** *self-pruning.*

pulpwood. Wood cut or prepared primarily for manufacture into wood pulp, for later manufacture into paper, fibreboard, or other products.
punky. A soft, weak, often spongy condition in wood; caused by decay.

Q

Q-value. The relationship between number of trees and diameter classes in an uneven-aged hardwood stand is a reversed J-shaped curve. The q-value is one mathematical expression of the shape of this curve. Quotients (q-value) can be calculated by dividing the number of trees in each DBH class by the number of trees in the next larger DBH class. The average of these quotients is the q-value for the stand.

quadratic mean diameter (**DBHq**). Diameter of the tree of average basal area.

R

radial check. A basal seam created by overgrowth of a persistent dead companion sprout (may represent a grading defect).

raptor. A bird of prey.

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

recruitment. Process of maintaining, restoring, or increasing the seedling and sapling component of a stand.

reforestation. The natural or artificial restocking of an area with forest trees.

regeneration. The renewal of a tree crop whether by natural or artificial means. Also the young crop itself which commonly is referred to as reproduction.

relascope. A simple instrument that can be used to estimate the basal area of forest stands without the need for laying down plots. This instrument is alternately described as an angle-gauge. ***see*** *prism.*

relative stand density. A measure of crowding in forest stands that takes into consideration the relative densities for individual species within the stand in question. The ratio of absolute density (trees/ha or BA/ha) to the density of a stand of the same size and species composition at maximum density.

release. Freeing a tree or group of trees from competition by cutting or otherwise eliminating growth that is overtopping or closely surrounding them.

removal cut. One or more cuts in the shelterwood system that releases established seedlings. The last removal cut is called the final removal cut.

reproduction.

- The process by which a forest is renewed:
    - **artificial**: Renewal by direct sowing or planting.
    - **natural**: Renewal by self-sown seeds, sprouts, rhizomes, etc.
- Seedlings or saplings of any origin.

reproduction methods.

- **clearcutting**: Removal of the entire forest in one cut. This method perpetuates even-aged stands.
- **seed-tree**: Removal of the mature timber in one cut, except for a small number of seed trees; called a group cutting when the seed trees are left in groups, a reserve cutting when specifically selected seed trees are left for growth, as well as to furnish seed.
- **selection**: Removal of mature timber, usually the oldest or largest trees, either as single scattered trees or in small groups at relatively short intervals, commonly 15 to 25 years, repeated indefinitely. This encourages a continuous establishment of natural reproduction and an uneven-aged stand is maintained.
- **shelterwood**: Removal of the mature timber in a series of cuttings, which extend over a period of years. Usually equal to not more than one-quarter (often not more than one-tenth) of the time required to grow the crop. The establishment of natural reproduction under the partial shelter of seed trees is encouraged, but sometimes these areas must be artificially regenerated.
- **coppice**: Forest regeneration by sprouting (vegetative reproduction) from stumps or roots.

reserve. An area of forest land that, by law or policy, is not available for harvesting. Areas of land and water set aside for ecosystem protection, outdoor and tourism values, preservation of rare species, gene pool, wildlife protection etc.

residual basal area. The basal area per hectare of acceptable trees left standing after harvest.

residual stand. Trees, often of sawlog size, left in a stand after thinning to grow until the next harvest. Also called leave trees.

residuals (**residual trees**). Trees left standing after harvesting.

resource technician. ***see*** *technician.*

resource values. Products or commodities associated with forest lands and largely dependent on ecological processes. These include, but are not limited to, water quality and quantity, forage, fish, wildlife, timber, recreation, energy, minerals and cultural and heritage resources.

rhizome. A horizontal stem that bears roots and leafy shoots.

riparian zone. That area adjacent to rivers and streams identified by vegetation, wildlife and other qualities unique to these locations.

roots. The below-ground tree or plant parts that provide physical support, absorb water and nutrients from the soil and store food produced by photosynthesis.

root graft. A functional union of two roots after their formation, commonly between roots of the same individual or roots of neighboring trees of the same species.

rotation. The period of years required to establish and grow a timber crop to a specified condition of maturity, when it may be harvested and a new tree crop started.

rotation age. The age at which a stand is considered ready for harvesting under an adopted plan of management.

rot. Wood in a state of decay.

roundwood. Wood products that are round (pulpwood, posts, poles, pilings, firewood, sawlogs).

S

salvage. To harvest trees that are dead or are in poor condition but can still yield a forest product.

samara. A dry, non-splitting, winged fruit, one- or two-seeded.

sample. A small collection from some larger population.

sample tree. A representative or average-size tree, chosen for detailed measurement of condition, size, growth, or quality.

sanitation cut. The removal of dead, damaged, or susceptible trees done primarily to prevent the spread of pests or pathogens and so promote forest hygiene.

sapling. A young tree of small diameter, typically 1 to 9 cm DBH.
sapwood. The light-coloured wood that appears on the outer portion of a cross section of a tree. Contains living cells; serves to conduct water and minerals to the crown.

sawlog. A log large enough to be sawn into lumber.

sawtimber. Trees that yield logs suitable in size and quality for the production of lumber.

scale. The estimated sound volume of a log or group of logs in terms of a given log rule or formula; used to estimate the sound volume of a log or group of logs.

scarify. To disturb the forest floor and top soil in preparation for natural regeneration or direct seeding or planting.

scavenger rot. A sap rot or heart rot most prevalent on declining or dying trees.

second growth. A second forest that develops after harvest of the original, natural forest.

secondary cavity-user. Wildlife that use decay cavities or ones abandoned by primary excavators.

seedbank. The store of dormant seeds buried in the soil.

seedbed. The soil, forest floor or other media on which seed falls.

seed cutting. Removal of trees in a mature stand to effect permanent openings in the canopy (if not done in a preparatory cutting) and thereby provide conditions for securing regeneration from the seed of trees retained for this purpose. Also the first of the shelterwood cuttings.

seed tree.

- A tree that produces seed.
- Trees reserved in a harvest operation to supply seed.

seed year. A year in which a given species produces a seed crop greatly in excess of the normal. Applied usually to trees of irregular or infrequent seed production.

seed zone. Areas of similar climatic and elevation conditions, used to specify where tree seed was collected and where trees from such seed are most likely to be successfully grown.

seedbed. In natural plant reproduction, the soil or forest floor on which seed falls; in nursery practice, a prepared area in which seed is sown.

seeding. A reforestation method by sowing seeds, aerially or by hand. Often done immediately after harvest so that a new forest is started the next growing season.

seedling. A small tree grown from seed. Usually the term is restricted to trees equal to or less than 1 cm DBH.

seep. A spot where water contained in the ground oozes slowly to the surface and often forms a pool. A small spring.

selection silvicultural system. A periodic partial-cutting, controlled by basal area, using vigour and risk characteristics to determine individual tree selection. An uneven-aged silvicultural system.

selective cutting. The cutting of individual selected trees. There are generally few if any control measures. Also known as high-grading. Not to be confused with the selection silvicultural system.

self-pruning. The natural death and fall of branches from live trees due to causes such as light and food deficiencies, decay, insect attack, snow and ice; also called natural pruning.

serotiny. Refers to cones that remain closed on the tree for one or more years and may open by exposure to temperature $\leq 50^{o}$ C.

shade tolerance. The capacity of a tree or plant species to develop and grow in the shade of and in competition with other trees or plants.

shake.

- A lengthwise separation of wood (usually caused by wind) that usually occurs between and parallel to the growth layers.
- A thin section split from a bolt of wood and used for roofing or siding.

shelterbelt. A wind barrier of living trees and/or shrubs, maintained to protect farm fields or homesteads.

shelterwood. The cutting method that describes the silvicultural system in which, in order to provide a source of seed and/or protection for regeneration, the old crop (the shelterwood) is removed in two or more successive shelterwood cuttings. The first cutting is ordinarily the seed cutting, though it may be preceded by a preparatory cutting and the last is the final cutting. Any intervening cutting is termed removal cutting. An even-aged stand results.

shelterwood silvicultural system. An even-aged silvicultural system where in order to provide a source of seed and/or protection for regeneration, the old crop is removed in two or more successive cuttings:

- **Group Shelterwood System**: Patches of advanced regeneration arising from thinnings or from natural disturbances, commonly developed in even-aged stands. Where this condition is prominent, shelterwood cuttings can be made specifically in relation to the requirements of each group of advanced regeneration. These clumps of regeneration are enlarged by the removal of all or most of the trees above them and initiating preparatory or seeding cuttings around them. The holes created in the canopy are gradually enlarged to keep pace with the establishment of reproduction.

- **Irregular Shelterwood System**: Harvest cutting in which opening of canopy is irregular and gradual; generally in groups, with the final cutting often is strips; regeneration natural; regeneration interval long, often up to half the rotation and the resultant crop considerably uneven-aged and irregular.
- **Strip Shelterwood System**: A shelterwood system in which regeneration cuttings are carried out on fairly wide strips, generally against the prevailing winds and progress rapidly; regeneration is mainly natural, regeneration interval short and resultant crop fairly even-aged and regular.
- **Uniform Shelterwood System**: A shelterwood system in which the canopy is opened fairly evenly throughout the regeneration area; regeneration is mainly natural, though it may be supplemented artificially; regeneration interval fairly short and resultant crop more or less even-aged and regular.

shrub. A woody perennial plant (lives more than one year) that differs from a perennial herb by its woody, persistent stems and from a tree by its low stature and branches that start from the base.

silvics. A knowledge of the nature of forests and forest trees, how they grow, reproduce and respond to changes in their environment.

silvicultural system. A process whereby forests are tended, harvested and replaced, resulting in a forest of distinctive form. Systems are classified according to the method of carrying out the fellings that remove the mature crop with a view to regeneration and according to the type of forest thereby produced.

silviculture. The art and science of producing and tending a forest; the theory and practice of controlling forest establishment, composition, growth and quality of forests to achieve the objectives of management.

silviculture prescription. A site-specific operational plan that describes the forest management objectives for an area. It prescribes the methods for harvesting the existing forest stand and a series of silviculture treatments that will be carried out to establish a free growing stand in a manner that accommodates other resource values as identified.

single tree selection. The cutting method that describes the silvicultural system in which trees are removed individually, here and there, each year over an entire forest or stand. The resultant stand usually regenerates naturally and becomes all-aged. ***see*** *selection silvicultural system.*

site. An area of land, especially with reference to its capacity to produce vegetation as a function of environmental factors (climate, soil, biology, etc.).

site class. A grouping of similar site indexes that indicates relative productivity. The common system in Ontario is Site Class X, 1, 2, 3, 4 (PFR).

site form. A numerical expression of forest site quality based on the height in metres (m), at a specified diameter (DBH) of dominant and codominant trees in a stand. Used for uneven-aged stands.

site index. A numerical expression of forest site quality based on the height in metres (m), at a specified age (usually age 50 years), of dominant and codominant trees in a stand. Used for even-aged stands.

site preparation. Any treatment of a forest site to prepare it for establishment of a plantation or for natural regeneration.

skid road (**skid trail**). A pathway over which logs are skidded.

skidder. A wheeled or tracked vehicle used for sliding and dragging logs from the stump to a landing.

skidding. The process of dragging logs from the woods to a landing.

slash.
- Tree tops, branches, bark and other debris, left after a forest operation; or
- The process of cutting down undesirable vegetation.

snag. A standing, dead tree or a standing section of the stem of a tree broken off at the height of six metres or more. If less than six metres, it is properly termed a stub.

softwood. One of the botanical group of trees that generally have needle or scale-like leaves-the conifers. Also the wood produced by such trees, regardless of texture or density.

soil horizon. A layer of soil with distinct characteristics that separate it from other soil layers.

soil moisture. The relative amount of water in the soil; usually applied to upper levels of soil, occasionally to humus layer.

soil profile. A vertical section of soil showing the nature and thickness of the various horizons, often used in soil classification.

soil series. Grouping of soils with similar profile characteristics.

spacing.
- The distance between trees in a plantation, a thinned stand, or a natural stand.
- The removal of undesirable trees within a young stand to control stocking, to maintain or improve growth, to increase wood quality and value, or to achieve other resource management objectives.

species (**of trees**). Trees having very similar genetic makeup, so that they freely interbreed and have common characteristics. In common language, a 'kind' or 'variety.' Each species is identified by a scientific name that consists of a genus portion and then a species portion (*Pinus strobus*, white pine).

species composition. The percentage of each recognized tree species comprising the forest type based upon the gross volume, the relative number of stems per hectare or basal area.

spikelet. An elongated inflorescence, consisting of one or more flowers.

spike top. A tree with a dead top, usually a mark of declining vigour.

sporangium. An organ in which spores are produced.

spore. A one-celled asexual reproductive organ. Almost exclusively associate with non-flowering plants (e.g. mosses, fungi).

sprout.

- Any shoot arising from a plant; or
- A young tree developed directly from the base, stump, or root of another tree. Relatively common among hardwoods.

squirrel's nest. A mass of branches and leaves similar in appearance to a stick nest, but usually less organized in appearance. The presence of old leaves is a good indicator.

stand. An aggregation of trees occupying a specific area and uniform enough in composition (species), age and arrangement to be distinguishable from the forest on adjoining areas.

stand density. The number of trees usually expressed on a per hectare basis.

stand structure. The distribution and representation of age and/or size classes and of crown and other tree classes within a stand.

stand table. A summary table showing the number of trees per unit area by species and diameter classes, for a stand or type. The data may also be presented in the form of a frequency distribution of diameter classes.

standard. Individual tree left to grow on to maturity.

stem. The trunk of a tree.

stick nest. A platform of sticks (twigs up to small branches) constructed by some bird species for nesting.

stocking.

- A measure of the proportion of the area in a stand actually occupied by trees expressed in terms of stocked quadrants or per cent of canopy closure. Usually expressed as trees per hectare or some relative measure (well stocked, fully stocked, overstocked, understocked).
- A qualitative expression of the adequacy of tree cover on an area, in terms of crown closure, number of trees, basal area or volume, in relation to a pre-established norm.
    - **fully stocked**: Productive forest land stocked with trees of a merchantable species. These trees by number and distribution or by average DBH, basal area, or volume are such that at rotation age they will produce a timber stand that occupies the potentially productive ground. The stocking , number of trees and distribution required to achieve this will usually be determined from yield curves. Sometimes called *normally stocked*.
    - **over stocked**: Productive forest land stocked with more trees of merchantable species than normal or full stocking would require. Growth is in some respect retarded and the full number of trees will not reach rotation age according to an appropriate yield and stock tables for the particular site and species.

stock table. A summary table showing the volume of trees per unit area by species and diameter classes, for a stand or type.

stolon. An elongate stem developing along the surface of the ground that takes root and forms new plants at the nodes or apex.

stone. A part of a drupe; consisting of a seed enclosed in a hard bony endocarp.

stratification. A pre-germinative treatment to break dormancy in seeds accomplished by exposing imbibed seeds to cold (2 to 5^{o} C) or warm conditions.

stub. A standing, dead tree or a standing section of the stem of a tree broken off at the height of six metres or less. If more than six metres, it is properly termed a snag.

stumpage. The value of timber as it stands uncut in the woods; in a general sense, the standing timber itself. Can also denote price paid for this timber.

succession. The replacement of one plant community by another in progressive development towards climax vegetation.

- *types of succession*:
    - **primary**: Plant succession on newly formed soils or surfaces, exposed for the first time, that have never borne vegetation.
    - **secondary**: Plant succession following the destruction of a part or all of the original vegetation.

sucker.

- A sprout from the lower portion of a stem, especially from the root.
- A shoot or tree originating from adventitious buds on roots.

sunscald. Death of cambial tissue on one side of a tree, caused by exposure to direct sunlight.

supercanopy tree. A living tree that sticks up well above the main canopy of a forest stand.

suppressed tree. ***see*** *overtopped*.

sustainability. The concept of producing a biological resource under management practices that ensure replacement of the part harvested, by re-growth or reproduction, before another harvest occurs.

sustainable development. Preservation and protection of diverse ecosystems-the soil, plants, animals, insects and fungi while maintaining the forest's productivity.

sustainable forest management. Management regimes applied to forest land which maintain the productive and renewal capacities as well as the genetic, species and ecological diversity of forest ecosystems.

sustained yield. A policy, method, or plan of forest management that calls for continuous production, to achieve, at the earliest practicable time, an approximate balance between net growth and amount harvested.

sweep. A gradual, but pronounced, bend in a log, pole, or piling; considered a defect.

swell-butted. Describes a tree greatly enlarged at the base.

T

tally. The count of trees, logs, or other products; to count trees, logs, or other products; to record products, distances, etc. as measured.

taper. The gradual reduction of diameter in a stem of a tree or a log from the base to the top.

technician. A person who has been technically educated in forestry at a forestry technical school or forestry college. A specialist in the technical details of a subject or occupation.

telluric water table. Water moving transversely in the soil and parent material, generally mineralized and with a fair supply of oxygen.

tending. Generally, any operation carried out for the benefit of a forest crop at any stage of its life, e.g. cleaning, thinning, pruning.

thinning. Cutting in an immature stand to increase the growth rate of the leave trees. The goal is to foster quality growth, improve composition, promote sanitation and recover and use material that would otherwise be lost to mortality. Thinning does not generally increase per-hectare volume growth, but it can increase lumber yield.

thinning from above. A thinning that favours the most promising (not necessarily the dominant) stems, with due regard to even distribution over the stand, by removing those trees that interfere with them. Also known as *crown thinning*.

thinning from below. A thinning that favours the dominants or selected dominants more or less evenly distributed over the stand by removing a varying proportion of the other trees. Also known as *low thinning*.

- *types of thinning*:
  - **low thinning**: The removal of trees from the lower crown classes in a stand. Also known as *thinning from below*.
  - **crown thinning**: The removal of trees from the middle and upper crown classes in a stand, to favour the most promising trees of these classes. Also known as *thinning from above.*
  - **selection thinning**: Removal of dominant trees to benefit trees in lower crown classes.
  - **free thinning**: Removal of trees to benefit best trees, regardless of crown class.
  - **mechanical thinning**: Removal of trees based totally on their spacing or arrangement. Also known as *row thinning*.

till. Glacial deposits laid down directly by the ice with little or no transportation or sorting by water.

timber. A term loosely applied to forest stands or their products; often applied to wood in forms suitable for heavy construction.

tolerance. The capacity of a tree or plant to develop and grow in the shade of (and in competition with) other trees or plants; a general term for the relative ability of a species to survive a deficiency of an essential growth requirement (light, moisture, nutrient supply).

top height. The mean height of 100 trees per hectare of largest diameter at breast height.

tree. A woody plant having one well-defined stem and a more or less definitely formed crown, usually attaining a height of at least three metres.

tree age. The number of years since the germination of the seed, or the budding of the sprout or root sucker.

tree length. Entire length of tree, or with the top lopped off at small diameter, as in skidding tree length to a landing for bucking into logs.

tree marking. Selecting and marking trees to be harvested and trees to be left to grow. Selected trees are usually identified with coloured paint on the tree trunk at DBH and at the stump. Normal colours used in Ontario are: orange/yellow for stem removal and blue for residual stems.

U

UGS - *unacceptable growing stock*. These trees have a high risk of dying and are expected to decline over the next cutting cycle. They include trees that are of poor form and/or low quality.

underbrush. The brush growing in a forest.

undergrowth. Small trees and shrubs and other plants growing under a forest canopy.

understory. That portion of the trees or other vegetation in a forest stand below the canopy.

uneven-aged. Applied to a stand in which there are considerable differences in the age of the trees and in which three or more age classes are represented.

uneven-aged management. The application of a combination of actions needed to simultaneously maintain continuous high-forest cover, recurring regeneration of desirable species and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single tree selection and group selection.

unmerchantable. A tree or stand that has not attained sufficient size, quality and/or volume to make it suitable for harvesting.

V

value-limiting defect. Such features are considered to be either:

- **Scaleable Defect**: such as rot or shake, that reduce sound useable volume or durability; or
- **Grade Defect**: such as knots or stain, that reduce strength or utility.

vegetative reproduction. Reproduction by a root, stem, leaf, or some other primary vegetative part of a plant body.

virgin forest. A forest essentially uninfluenced by human activity.

volume. The amount of wood in a tree, stand or other specified area according to some unit of measurement or some standard of use (e.g. m^3 or m^3/ha)

- **Gross Total Volume** (**GTV**): Volume of the main stem, including stump and top as well as defective and decayed wood, of individual trees or stands.
- **Gross Merchantable Volume** (**GMV**): Volume of the main stem, excluding a specified stump and top, but including defective and decayed wood, of individual trees or stands.
- **Net Merchantable Volume** (**NMV**): Volume of the main stem, excluding stump and top as well as decayed wood, of individual trees or stands.

volume table. A table showing gross volume of trees, based on given tree measurements (usually DBH and height).

W

weed tree. A tree of a species with relatively little or no value.

wetland. Land that is seasonally or permanently covered by shallow water, or land where the water table is close to or at the surface. In either case, the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic or water-tolerant plants.

whiteface basal wound. Wound with a dry, casehardened surface usually associated with localized stain and very limited decay, if any. They are neither ground contact nor cupped to retain water.

whorl. A group of branches originating at or near the base of the terminal bud. Generally, one whorl is produced each growing season.

widowmaker. Any limb, top, leaning tree, or other material in the forest that is in danger of falling to the ground without warning, creating a safety hazard. Often applied to limbs that get lodged in the crowns of other trees during a logging operation.

wilderness area. A rather large, generally inaccessible area left in its natural state and available for recreation experiences. It is void of development except for those trails, sites and similar conditions made by previous wilderness users.

wildlife. Undomesticated vertebrate animals, except fish, considered collectively.

wildlife trees. A wildlife tree is a standing live or dead tree with special characteristics that provide valuable habitat for the conservation or enhancement of wildlife. Characteristics include age, diameter and height for the site, current use by wildlife, species value, location and relative scarcity.

wild life. All wild mammals, birds, reptiles, amphibians, fishes, invertebrates, plants, fungi, algae, bacteria and other wild organisms.

windfall. A tree uprooted or broken off by wind; an area on which the trees have been thrown by wind. ***see*** *windthrow*.

windfirm. Descriptive of trees and plantations that, because of species, soil or relative exposure, are unlikely to suffer windthrow.

windthrow. Uprooting or breakage of trees caused by strong winds.

witches'-broom. An abnormal tufted growth of small branches on a tree or shrub caused by fungi or viruses.

wolf tree. A vigorous tree that has merchantable value but occupies more space than its value warrants. Usually very limby.

wood. The lignified water-conducting, supporting and storage tissue of branches, stems and roots.

wood-processing industry. That segment of the forest industry that manufactures lumber, paper, plywood and other primary forest products.

working group. An inventory aggregation for management purposes. An aggregate of stands, including potential forest areas assigned to this category, having the same predominant species and managed under the same rotation or cutting cycle and broad silvicultural system.

X

xylem. A complex tissue in the vascular system of higher plants that consists of vessels, tracheids, or both together with wood fibres and parenchyma cells, functions chiefly in conduction but also in support and storage and typically constitutes the woody element.

Y

yard. A place where logs, pulpwood, or other timber is collected; to collect logs in a yard, landing, or skidway.

yield.

- The harvest, actual or estimated, howsoever measured, over a given period of time.
- Growth or increment accumulated by trees at specified ages expressed by volume or weight to defined merchantability standards.

yield curve. A graphical or mathematical representation of the yield of a given species, on a given site, at a given time.

yield table. A summary table showing, for stands (usually even-aged stands) of one or more species on different site qualities, characteristics at different ages of the stand. The stand characteristics usually include average diameter and height and total basal area, number of trees and volume per hectare.

- **Empirical**: Prepared for actual average stand conditions.
- **Normal**: Prepared for normally stocked stands.
- **Variable Density**: Prepared for stands of varying density expressed as numbers of trees per hectare.

young growth. Any forest of relatively young age and condition.

Z

zero net growth. A condition that occurs when any new growth in a forest or tree is equal to mortality or decay. This is a temporary, stagnant growth condition.

GLOSSARY OF TECHNICAL TERMS

GLOSSARY OF SCIENTIFIC NAMES

COMMON NAME	SCIENTIFIC NAME	SYNONYM
American elm	*Ulmus americana* L.	
American marten	*Martes americana*	
artist's conk	*Ganoderma applanatum* (Pers.:Wallr.) Pat.	*Fomes applanatus* (Pers.:Wallr.) Gill
Armillaria “complex” shoestring root rot	*Armillaria* species *Armillaria ostoyae* (Romagn.) Herink	
bald eagle	*Haliaeetus leucocephalus*	
balsam fir	*Abies balsamea* (L.) Mill.	
balsam poplar	*Populus balsamifera* L.	
barred owl	*Strix varia* Barton	
basswood	*Tilia americana* L.	
beaver	*Castor canadensis*	
beech	*Fagus grandifolia* Ehrh.	
beech bark disease	*Nectria coccinea* Pers.: Fr. var. *faginata* Lohm., Wats. et Ay.	
beech scale	*Cryptococcus fagisuga* Lindinger	
black ash	*Fraxinus nigra* Marsh.	
black bear	*Ursus americanus* Pallas	
blackburnian warbler	*Dendroica fusca* Muller	
black cherry	*Prunus serotina* Ehrh.	
black knot	*Apiosporina morbosa* (Schw.) von Arx	*Dibotyron morbosum* Th. et Syd.
black spruce	*Picea mariana* (Mill.) B.S.P.	
black walnut	*Juglans nigra* L.	
broad-winged hawk	*Buteo platypterus* Vieillot	
brown creeper	*Certhia americana*	
brown mottled rot	*Pholiota spectabilis* (Fr.) Kummer	
Chickadee, black-capped	*Parsus atricapillus* L.	
clinker fungus	*Inonotus obliquus* (Pers.: Fr.) Pilat	*Poria obliqua* (Pers.:Fr.) Karst.
coal fungus	*Hypoxylon deustum* (Hoff. ex Fries) Grev	
cobra canker	*Eutypella parasitica* Dav. & Lor.	*Ustulina vulgaris* Tul.
Cooper's hawk	*Accipiter cooperii* Bonaparte	
common goldeneye	*Bucephala clangula* L.	
common raven	*Corvus corax*	
deer mouse	*Peromyscus maniculatus* (Wagner)	
downy woodpecker	*Picoides pubescens* L.	
eastern bluebird	*Sialia sialis*	
eastern white cedar	*Thuja occidentalis*	
false tinder fungus	*Phellinus igniarius* (L.:Fr) Quel.	*Fomes igniarius* (L.:Fr) Kickx
fisher	*Martes pennanti* Erxleben	
flicker	*Colaptes auratus* L.	
forest tent caterpillar	*Malacosoma disstria* Hubner	
great blue heron	*Ardea herodias*	
great crested flycatcher	*Myiarchus crinitus* L.	
great horned owl	*Bubo virginianus* Gmelin	
green ash	*Fraxinus pennsylvanica* Marsh var. *lanceolata* (Borkh.) Sarg.	
grey squirrel	*Sciurus carolinensis* Gmelin	
golden pholiota	*Pholiota aurivella* (Fr.) Kum.	

COMMON NAME	SCIENTIFIC NAME	SYNONYM
hart's tongue fern	*Phyllitis Scolopendrium* (L.) Newm.	
heart rot	*Phellinus laevigatus* (Fr.) Bourd. et Galz.	*Fomes igniarius laevigatus* (Fr.) Overh.
hemlock	*Tsuga canadensis* (L.) Carr.	*Hydnum erinaceus* Bull.:Fr.
hedgehog fungus	*Hericium erinaceum* (Bull.:Fr.) Pers.	
hooded merganser	*Lophodytes cucullatus*	
ironwood	*Ostrya virginiana* (Mill.) K. Koch	
jack pine	*Pinus banksiana* Lamb.	
largetooth aspen	*Populus grandidentata*	
marten	*Martes americana* Turton	
merlin	*Falco columbarius*	
moose	*Alces alces* L.	*Fomes connatus* (Weinm.:Fr) Gill.
mossy top fungus	*Oxyporus populinus* (Sokum.:Fr.) Donk	
northern goshawk	*Accipter gentilis* L.	
northern flicker	*Colaptes auratus*	
northern saw-whet owl	*Aegolius acadicus* (Gmelin)	
northern two-lined salamander	*Eurycea bislineata*	
northern water shrew	*Sorex palustris*	
osprey	*Pandion haliaetus*	
peregrine falcon	*Falco peregrinus*	
pileated woodpecker	*Dryocopus pileatus* L.	
poplar	*Populus* spp.	
porcupine	*Erethizon dorsatum* L.	
punk knot	*Inonotus glomeratus* (Pk.) Murr.	*Polyporus glomeratus* Pk.
raccoon	*Procyon lotor* L.	
red-backed salamander	*Plethedon cinereus*	
red-backed vole	*Clethrionomys gapperi* (Vigors)	
red-breasted nuthatch	*Sitta canadensis*	
red maple	*Acer rubrum*	
red oak	*Quercus rubra* L.	
red oak borer	*Enaphalodes rufulus* (Haldeman)	
red pine	*Pinus resinosa*	
red-shouldered hawk	*Buteo lineatus* Gmelin	
red spruce	*Picea rubra*	
red squirrel	*Tamiasciurus hudsonicus* (Erxleben)	
red-tailed hawk	*Buteo jamaicensis* Gmelin	
ruffed grouse	*Bonasa umbellus* L.	
sapsucker	*Sphyrapicus varius* L.	
sapstreak disease	*Ceratocystis coerulescens* (Muench) Bak.	
screech owl	*Otus asio* L.	
shagbark hickory	*Carya ovata* (Mill.) K. Koch	
sharp-shinned hawk	*Accipiter striatus* Vieillot	
silver maple	*Acer saccharinum* L.	
southern flying squirrel	*Glaucomys volans* L.	
spine tooth	*Climacodon septrionalis* (Fr.) Karst	*Hydnum septentrionalis* Fr.
sugar maple borer	*Glycobius speciosus* (Say)	
spotted salamander	*Ambystoma maculatum*	
sugar maple	*Acer saccharum* Marsh.	

sugar maple borer	*Glycobius speciosus* (Say)	

COMMON NAME	SCIENTIFIC NAME	SYNONYM
sulphur fungus	*Laetiporus sulphureus* (Bull.:Fr) Bond et Singer	*Polyporus sulphureus* Bull.:Fr
tamarack	*Larix laricina* (Du Roi) K. Koch	
target canker	*Nectria galligena* Bres.	
tinder fungus	*Fomes fomentarius* (L.:Fr.) Kickx	
trembling aspen	*Populus tremuloides*	
turkey vulture	*Cathartes aura*	
varnish conk (hemlock)	*Ganoderma tsugae* Murr.	
varnish conk (hardwoods)	*Ganoderma lucidum* (Leys. ex Fr.) Karst	
white ash	*Fraxinus americana* L.	
white birch	*Betula payrifera* Marsh	
white breasted nuthatch	*Sitta carolinensis* Latham	
white heart rot	*Stereum murraii* (Berk. et Curt.) Burt	*Cystostereum murraii* (Berk. et Curt.) Pouz.
white oak	*Quercus alba* L.	
white-tailed deer	*Odocoileus virginianus* Zimmerman	
white pine	*Pinus strobus* L.	
white spruce	*Picea glauca* (Moench) Voss	
wood duck	*Aix sponsa* L.	
yellow bellied sapsucker	*Sphyrapicus varius* L.	
yellow birch	*Betula alleghaniensis* Arnold	

GLOSSARY OF SPECIES ABBREVIATIONS

Abbreviation	Tree Species
Ab	black ash
Ag	green ash
Aw	white ash
Bd	basswood
Be	American beech
Bf	balsam fir
Bw	white birch
By	yellow birch
Cb	black cherry
Cw	eastern white cedar
Ea	American elm
He	eastern hemlock
Id	ironwood
Mh	sugar maple
Mr	red maple
Ms	silver maple
Or	red oak
Ow	white oak
Pj	jack pine
Pt	trembling aspen
Pl	largetooth aspen
Pb	balsam poplar
Pw	white pine
Pr	red pine
Sb	black spruce
Sw	white spruce
Sr	red spruce
La	tamarack
Wb	black walnut

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