A Silvicultural Guide for the Tolerant Hardwood Forest in Ontario

Version 1.1

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Preface

"*A Silvicultural Guide for the Tolerant Hardwoods Working Group in Ontario*" (Anderson *et al.* 1990) has been the principal source of information related to the management of tolerant hardwood forests in central and southern Ontario. Much of the information provided in that document remains unchanged in this publication. However, since 1990 there have been significant advances in the understanding of, and approaches to, forestry practice. Of particular note are the recent completion of the forest ecosystem classification system for the area, and OMNR's increased focus on ecological sustainability. This document will attempt to encompass much of that information as it pertains to the management of Ontario's tolerant hardwood forests.

Acknowledgments

The Tolerant Hardwood Silvicultural Guide Writing Team Coordinator is indebted to the members of the writing team for their work as co-authors in the preparation of this guide. The team consisted of:

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The authors wish to acknowledge the contributions of information, knowledge, and experience from several organizations and individuals deserving special recognition.

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MNR's Strategic Directions and Statement of Environmental Values

The Ontario Ministry of Natural Resources (OMNR) 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 the 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* and the later released *Direction 90s—Moving Ahead 1995*. Those strategic directions are also considered in Ministry land use and resource management planning.

More recently, in 1994, the Ministry of Natural Resources finalized its Statement of Environmental Values (SEV) under the Environmental Bill of Rights (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 Al Corlett, Brian Naylor and Fred Pinto

Silvicultural guides serve as sources of knowledge and guidance that enable forest managers to evaluate the ecological factors relevant to each forest stand. Silvicultural guides assist in the development of the most appropriate treatments to meet management objectives. The guides also implicitly include the appropriate rules and regulations that society has deemed necessary to conduct forestry operations.

There is wide societal acceptance that ecological sustainability is a fundamental principle in resource management. In Ontario, the concern for ecological sustainability has been encoded into law and policy that govern natural resource use. For example, *The Crown Forest Sustainability Act* (RSO 1995) requires that the forests of Ontario be managed in a manner that maintains ecological sustainability. This means that the tolerant hardwood forests of Ontario will be managed to produce a variety of forest products including high quality lumber while maintaining productive capacity, site quality, wildlife habitat and biological diversity.

Attaining this goal requires the application of silvicultural practices that regenerate desirable species and improve or maintain stand quality. At the same time, managed stands must have a composition, structure, and ecological function similar to that produced by agents of natural disturbance. These two objectives are more often than not complementary, as the most effective and efficient silvicultural practices tend to be those that recognize and take advantage of natural adaptations and natural processes.

This guide attempts to ensure human activity more closely emulates natural processes in the Great Lakes-St. Lawrence tolerant hardwood forest. It must be recognized however, that human understanding of ecosystem function and natural processes is incomplete, and practical means of mimicking nature are not available in all cases. This suggests that there are important differences between natural processes and human activities. Therefore, this guide should be considered a “work in progress”.

The term *working group* is used to categorize all “productive” forest land in Ontario for the purposes of the Forest Resources Inventory (FRI). The “tolerant hardwood forest” is an aggregate of three interrelated *working groups* currently differentiated by the Forest Resources Inventory as: 1) **Hard Maple Working Group**, 2) **Yellow Birch Working Group**, and 3) **Other Hardwoods Working Group**. This guide provides information on the seven principal species commonly found in these three groups: sugar maple, American beech, yellow birch, red oak, white ash, black cherry and basswood. Managers interested in silviculture of Great Lakes-St. Lawrence conifer species or boreal tree species should refer to *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario* or *Silvicultural Guide to Managing for Black Spruce, Jack Pine and Aspen on Boreal Forest Ecosites in Ontario*, respectively.

These three inventory *working groups* have a natural relationship since all seven species may occur together as associates in most localities, often within a single stand. The term *tolerant hardwood*, however, is one of convenience, since not all associated species are tolerant of shade (e.g. yellow birch and black cherry).

This guide deals with the management of *even-aged* and *uneven-aged* forests that usually have been lightly cut over, often several times. Such man-made disturbances, along with others such as those caused by fire, wind, and insect infestation, in combination with site factors and silvical characteristics of each species, have strongly influenced the tolerant hardwood forest in terms of stand structure, stocking levels, growth, and quality, as well as species composition.

Forest management is a planned process of interdependent treatments designed to modify, improve, utilize and regulate the forest. The detail in this guide will assist in the development of suitable management strategies and the writing of effective silvicultural prescriptions based on interpretation of local site quality, species' silvical requirements, stand characteristics, economic product requirements and biotic and environmental sensitivities.

The guide serves as a source of experiential and experimental knowledge. In some cases the amount of information available is limited, or the variability in site and stand conditions is high and specific recommendations cannot be made in this guide. The guide should be used as an aid to thoughtful professional practice and not as a source of generic rules to develop simplistic silvicultural prescriptions.

Silvicultural practice is applied forest ecology (Smith *et al.* 1996). Sections 2.0 through 8.0 provide a summary of existing information on abiotic (values, distribution, site and climate), and biological factors (silvics, genetics, growth and yield and quality), while Sections 9.0 through 12.0 provide forest managers with recommended strategies and standards to manage human activities in the forest.

2.0 RANGE AND IMPORTANCE

2.0 Range and Importance

by Harvey Anderson, Carl Corbett and Brenda Chambers

The tolerant hardwood forest occupies a broad geographic range in Ontario and is noted for its' high-value products. Sections 2.1 and 2.2 provide a description of the geographic distribution of the seven principal species, their relative local abundance and importance and the relative position of each species in a scale of commercial values, all of which affect the intensity of timber management that can be justified locally.

2.1 Range

The distribution of the tree species associated with the tolerant hardwood forest is confined in Ontario to the Great Lakes-St. Lawrence and the Deciduous Forest Regions described by Rowe (1972). These regions represent major geographic zones, characterized vegetationally by a broad similarity both in physiognomy and in composition of the dominant tree species. Climate is not used as a factor in any delineation.

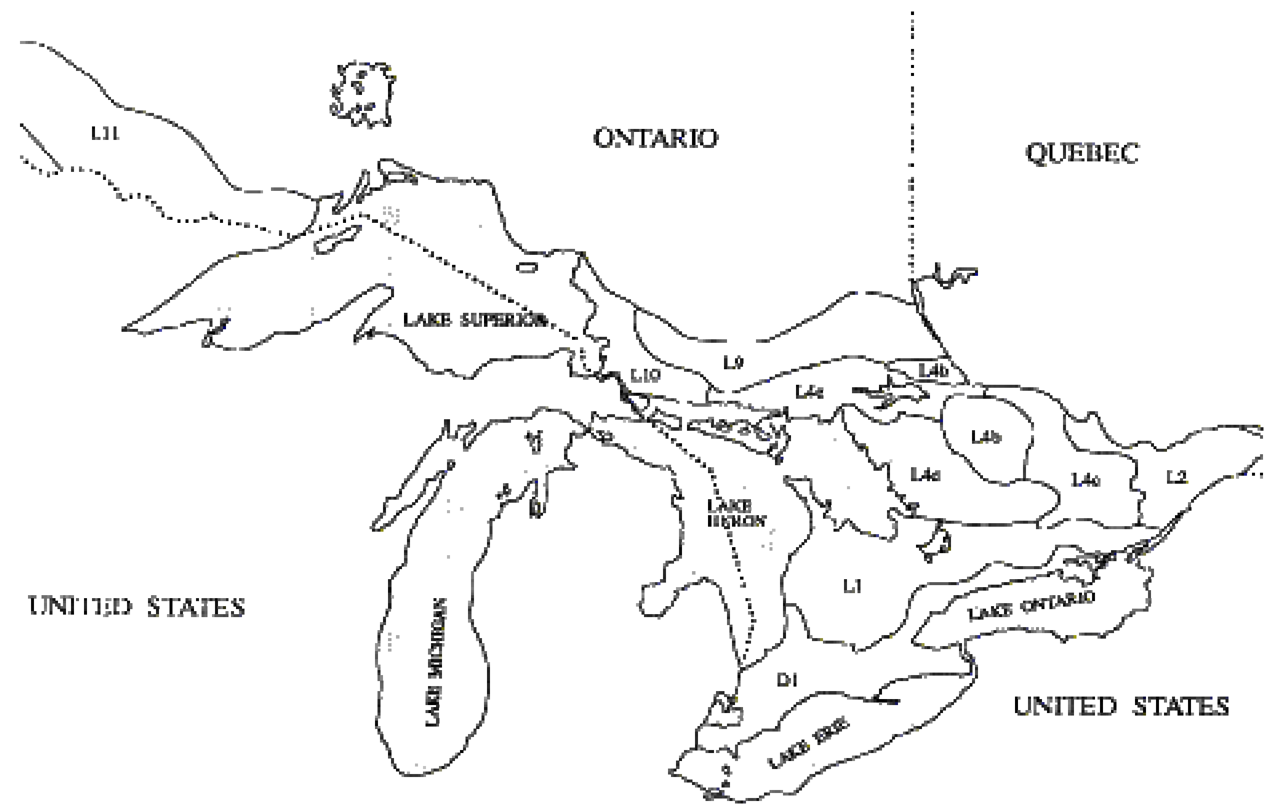
The Deciduous Forest Region (***see*** FIGURE 2.1.1) contains a single section (D1) and represents the northern edge of a hardwood forest of widespread occurrence in the eastern United States. While it contains some species characteristic of the Great Lakes-St. Lawrence Forest Region to the north (such as sugar maple, beech and locally, hemlock), it contains many species peculiar to this region such as walnut, sycamore, sassafras, swamp white oak, black gum and others.

The Great Lakes-St. Lawrence Forest Region is subdivided into ten sections (nine of which contain tolerant hardwoods), which are geographic areas "possessing an individuality that is expressed relative to other sections in a distinctive patterning of vegetation and of physiography." The Great Lakes-St. Lawrence Forest Region is characterized by hemlock and yellow birch, as well as white and red pine. Associated with hemlock and yellow birch are other representatives of the tolerant hardwood forest of wider distribution, such as sugar maple, beech, red oak, white ash, basswood and black cherry.

The geographic (botanical) distributions of eight of the species (the seven principal species plus hemlock) characteristic of this forest are illustrated in FIGURE 2.1.1. The significance of the seven principal species varies within the nine sections of the Great Lakes-St. Lawrence Forest Region. The tree species are divided into three distinct "working groups".

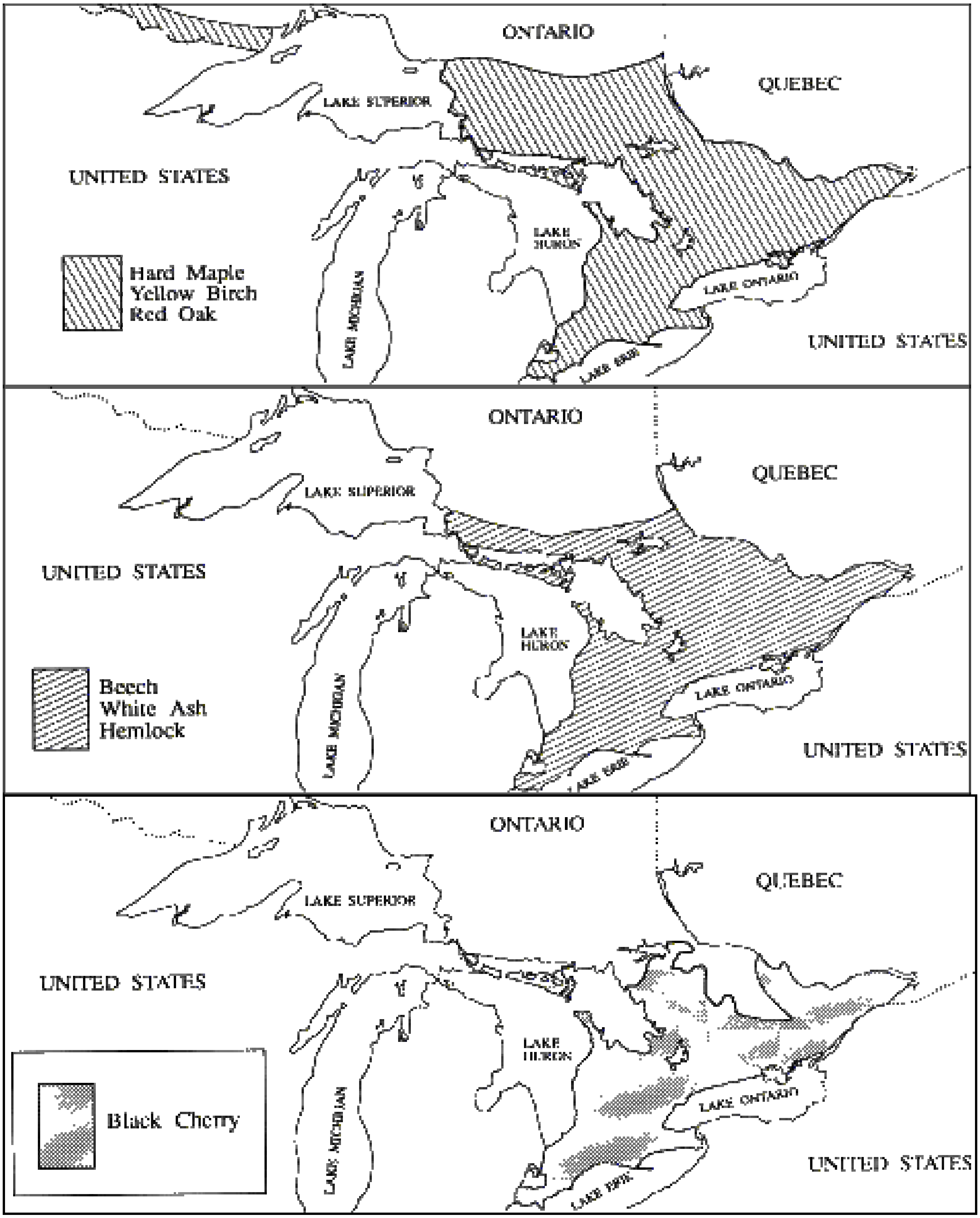
The limits of distribution and dominance of species within and among sections are related not only to the local history of disturbance but more specifically to variation in site and to the species' particular ecological requirements. These local effects will be discussed further in Section 3.0, "Site" and Section 4.0, "Silvics."

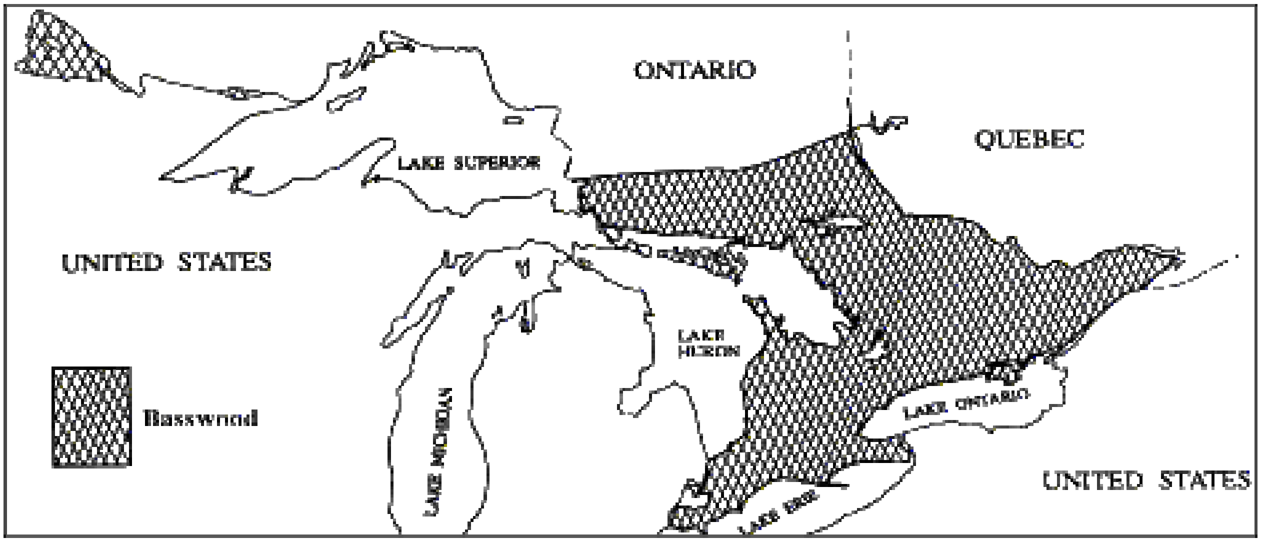
FIGURE 2.1.1: Forest regions and sections of Ontario associated with the tolerant hardwood forest (*from*: Rowe [1972])



FOREST REGION	**FOREST SECTION**	
Great Lakes-St. Lawrence	L1	Huron-Ontario
Great Lakes-St. Lawrence	L2	Upper St. Lawrence
Great Lakes-St. Lawrence	L4b	Algonquin-Pontiac
Great Lakes-St. Lawrence	L4c	Middle Ottawa
Great Lakes-St. Lawrence	L4d	Georgian Bay
Great Lakes-St. Lawrence	L4e	Sudbury-North Bay
Great Lakes-St. Lawrence	L9	Temagami
Great Lakes-St. Lawrence	L10	Algoma
Great Lakes-St. Lawrence	L11	Quetico
Deciduous	D1	Niagara

FIGURE 2.1.2: Botanical ranges of species in the tolerant hardwood forest in Ontario (*from:* Fowells [1965])





The commercial range of the tolerant hardwood forest occupies most of Ontario south of the transitional forest. In the transitional forest (Sections L.9, L.10 and L.11), stands become more scattered, tending to occupy only the better sites and have often been affected by a history of fires and logging. In the extreme northwest (L.11), tolerant hardwood forest species occur as outliers.

As noted earlier, the tolerant hardwood forest is divided into three inventory working groups. The commercial range of the **Hard Maple Working Group** extends throughout its distribution, although its quality may often be severely restricted in the northern portions of the transitional forest (Sections L.9, L.10 and L.11). The **Yellow Birch Working Group** occurs commercially from its northern limit southward to Section L.4d, but rarely attains a dominant stand position in more southerly areas of Section L.1 or in the Deciduous Forest Region. Although it is not uncommon to find representatives of all or many of the seven principal species within a single working group (subject to range limitations), the **Other Hardwoods Working Group** becomes more common toward the southern portion of the province, generally south of Section L.4e. Most of the three working groups become more species-rich as their occurrence moves south. Within the general ranges, however, higher elevation effects may eliminate local occurrences of some species; this happens, for example, in Section L.4b with white ash, black cherry and red oak.

Minor species components occurring less abundantly and less regularly in the northern part of the tolerant hardwood forest range are basswood, red maple, black ash, white elm, white pine, white spruce and red spruce. These associations are similar to those found in the northern hardwood and Appalachian mixed hardwood forest types of the United States (Burns 1983). Farther south, the tolerant hardwoods may blend with “Carolinian” species (including black maple) to produce a very heterogeneous hardwood forest.

2.2 Commercial Importance

2.2.1 Supply

The majority (99.4 per cent) of the provincial tolerant hardwood growing stock (on Crown and patent lands) is located in the Southcentral and Northeast Administrative Regions of OMNR (OMNR 1996). The tolerant hardwoods are distributed on more than 3.6 million hectares and have a gross total volume (GTV) of 562 million cubic metres, including hemlock (OMNR 1996).

The Hard Maple Working Group is the largest in the tolerant hardwood forest. It comprises 73 per cent of the area and 75 per cent of the gross total volume. It is followed by the Other Hardwoods Working Group (22 per cent and 20 per cent, respectively) and the Yellow Birch Working Group (5 per cent and 5 per cent).

2.2.2 Consumption

Total harvest of tolerant hardwood forest species (including hemlock) was 0.65 million cubic metres in 1988-89 (OMNR 1991). Of this total, 43 per cent was sugar maple, 11 per cent was yellow birch, 5 per cent was hemlock, 4 per cent was beech, 3 per cent was oak, 2 per cent was ash, basswood and cherry, while the remaining 32 per cent was composed of other tolerant hardwoods (species were undifferentiated).

Tolerant hardwood forest species represented 3.2 per cent (645,772 m^3) of the total 1988-89 provincial harvest and contributed 2.2 per cent of stumpage revenue. The tolerant hardwood species harvest was 427,018 m^3 in 1983-84 (2.3 per cent), 807,857 m^3 in 1985-86 (4.1 per cent) and 825,945 m^3 in 1986-87 (4.0 per cent) (OMNR 1988).

Approximately 62 per cent of forest stumpage revenue in the tolerant hardwood forest is attributed to sugar maple and yellow birch (OMNR 1991).

As illustrated above, tolerant hardwood forest species have greater local significance than might be implied by their overall provincial contribution. For example, on a forest section basis, maple comprises 29 per cent, 49 per cent and 45 per cent by area in the Algonquin-Pontiac, Georgian Bay and Algoma forest sections, respectively (CFS 1995).

Although average stumpage value was less than average volume produced in 1988/89, this is not indicative of the potential value of tolerant hardwoods. Rather, it reflects the typical yield from previously unmanaged tolerant hardwood stands, which generally contain a high percentage of grade 2 logs with relatively low stumpage value.

Any silvicultural practice that upgrades the sawlog or veneer log yields of a forest stand will increase relative stumpage value.

2.2.3 Economic value

The sawlog and veneer value of the mid-tolerant species (yellow birch, red oak, white ash and black cherry) tends to be somewhat higher than that of the more shade-tolerant sugar maple and beech. There is considerable variance within those groupings as well, with red oak grade 1 sawlog material often having more than 30 per cent higher value than a yellow birch grade 1 sawlog. Actual values fluctuate considerably with changing market conditions (which in turn reflect consumer preference and wood supply).

The value differential related to log quality is also significant. Grade 1 tolerant hardwood sawlogs commonly show a delivered-to-the-mill value at least 30 per cent greater than grade 2. A quality veneer log may have more than double the commercial value of a similar sized sawlog. In hardwoods, log value is based on appearance and freedom from defect, while in softwoods it is related primarily to strength. The various grades of hardwood lumber maintain price differentials that reflect these quality criteria. The price of a best grade (FAS) is commonly 20 per cent higher than that of a medium grade (No. 1 Common), which in turn is often 180 per cent higher than the lowest commercial grade (No. 3 Common).

2.2.4 Significance to the forest industry

Most of the processed lumber and veneer material is directed to the furniture, flooring, paneling, tie, pallet and coffin/casket industries while the lower grades of hardwood are used for pulpwood and fuelwood. Each stage of manufacture, from stump to final product contributes to the value added price, with actual value added being a function of tree quality and species.

Where tree quality levels in the forest improve as a result of intensive management efforts, opportunities for the production of the higher value end-products noted above also increase, with resultant benefits to the forest industry and Ontario’s economy. Marked quality improvement over a period of one to three cutting cycles is possible, depending on site and initial stand condition. Examples of up to an 85 per cent increase in the recovery of *No. 1 Common* and better lumber following a single improvement cut have been noted (Carl Corbett, personal communication). Thus, the objective of increasing the levels of acceptable growing stock over time will be of particular significance to the forest industry.

3.0 SITE

3.0 Site

by Brenda Chambers, Harvey Anderson and Barb Merchant

The distribution, character and productivity of Ontario's forests are controlled by the interacting effects of climate, landform, soils, vegetation and disturbance. This control is especially true for the tolerant hardwood forests of the province, in which performance and quality are sensitive to both macro- and micro-variations in site. Forest ecosystem classification systems provide a useful means of better understanding those interrelationships, and thus facilitate the development of predictive tools that accommodate those variations.

3.1 Climate

The effect of climate on the tolerant hardwood forests of Ontario is modified by latitude, landform and proximity to the Great Lakes. Two climatic characteristics that appear to significantly affect tolerant hardwoods are: 1) the decrease in summer temperature from south to north, with the isotherms showing a "continental" tilt from northwest to southeast, and 2) the trend of atmospheric humidity from a drier west to a more humid east. In addition, weather is quite variable because of the occurrence of storm-tracks of continental-polar and -tropical air masses (Hills 1959).

Precipitation varies from 550 to 1,018 mm per year (MacKey *et al.* 1996), depending on the location, slope, and elevation of land masses relative to water masses and prevailing wind direction. Areas in the lee of large lakes have more cloud, more precipitation, and more moderate temperatures than other locations. Of note are the high winter precipitation levels on the windward sides of the Algonquin and Algoma Highlands and east of Lake Huron (FIGURE 3.0.1). Further to the east, in the Ottawa Valley, drier conditions prevail in the rain shadow of the Algonquin Highlands.

Minimum temperatures and growing degree days are substantially higher within 30 km of any of the Great Lakes (FIGURE 3.0.2; FIGURE 3.0.3), reducing the risk of early fall frost and lengthening the growing season by as much as 10 days. The shortest growing season occurs in Hill's Site Region 4W, the longest in Site Region 7E (TABLE 3.0.1; FIGURE 3.0.4). In central Ontario, the shortest frost-free period and the fewest growing degree-days occur in Algoma (100 days and 1,333 days, respectively) and in the Algonquin Highlands (90 and 1,555), while the highest values for these climatic features have been recorded on Pelee Island (180 and 2,444) (Brown *et al.* 1974).

Local climate is affected by aspect and slope, southern exposures being hotter and drier than northern. Fog and frost-pockets occur in air-locked depressions, encouraging the development of vegetation characteristic of more northerly regions. Similarly, protected upper slopes with good air drainage and southerly aspects have vegetation representative of more southerly areas.

FIGURE 3.0.1: Precipitation for the 3-month period prior to the start of the growing season (*from:* MacKey *et al.* [1996])

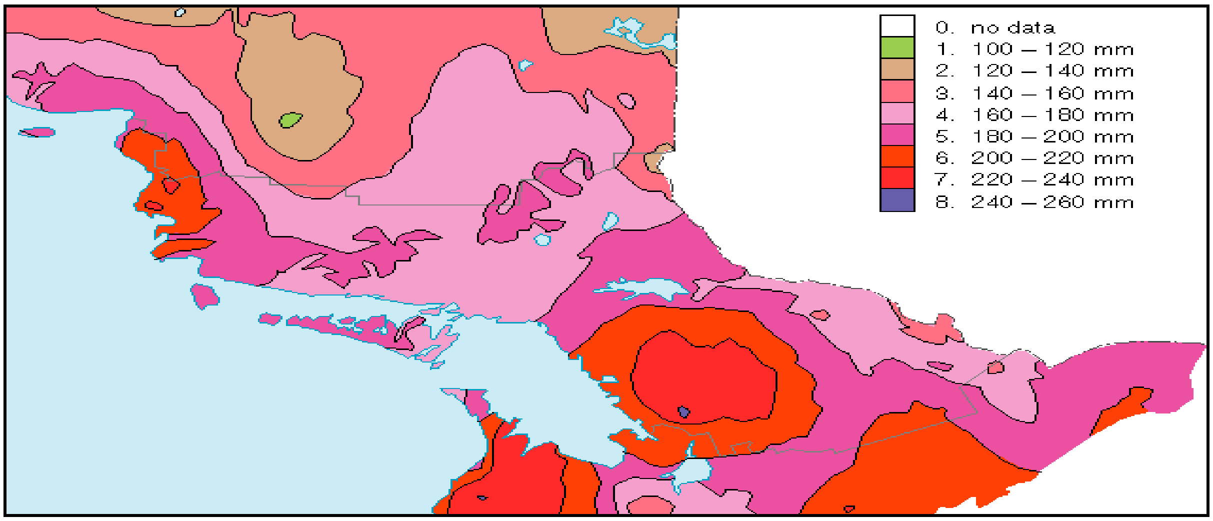


FIGURE 3.0.2: Mean temperature of the coldest month of the year (*from:* MacKey *et al.* [1996])

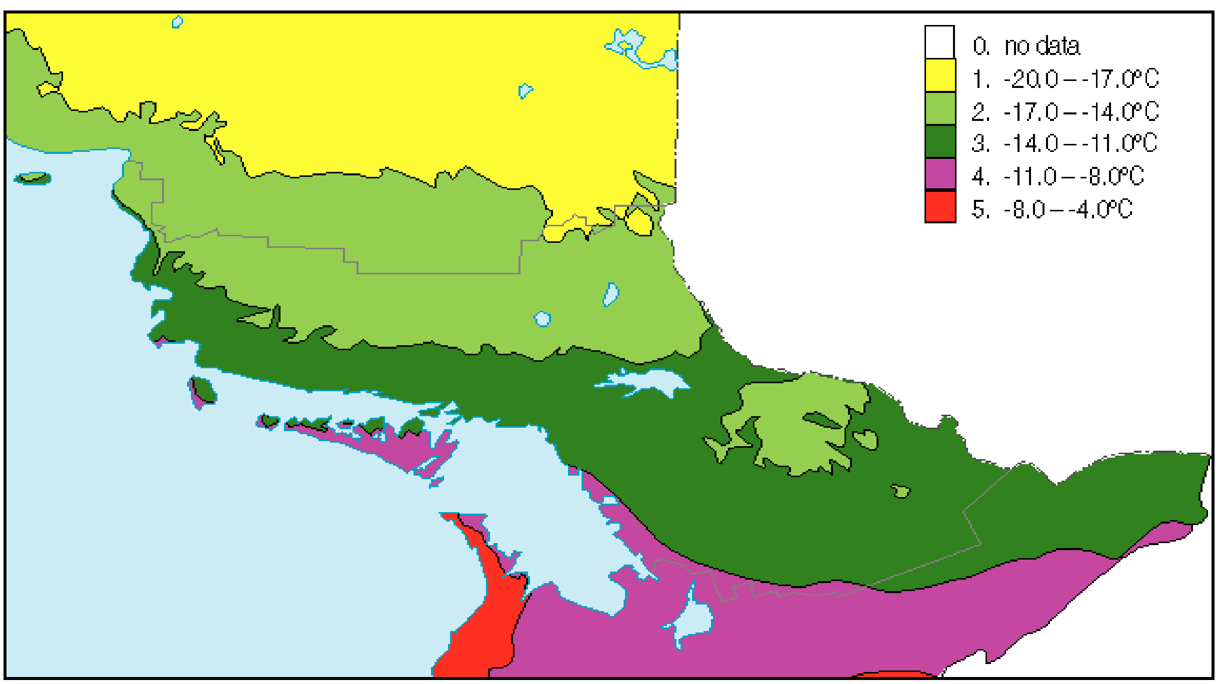


FIGURE 3.0.3: Growing degrees days per year (*from:* MacKey *et al.* [1996])

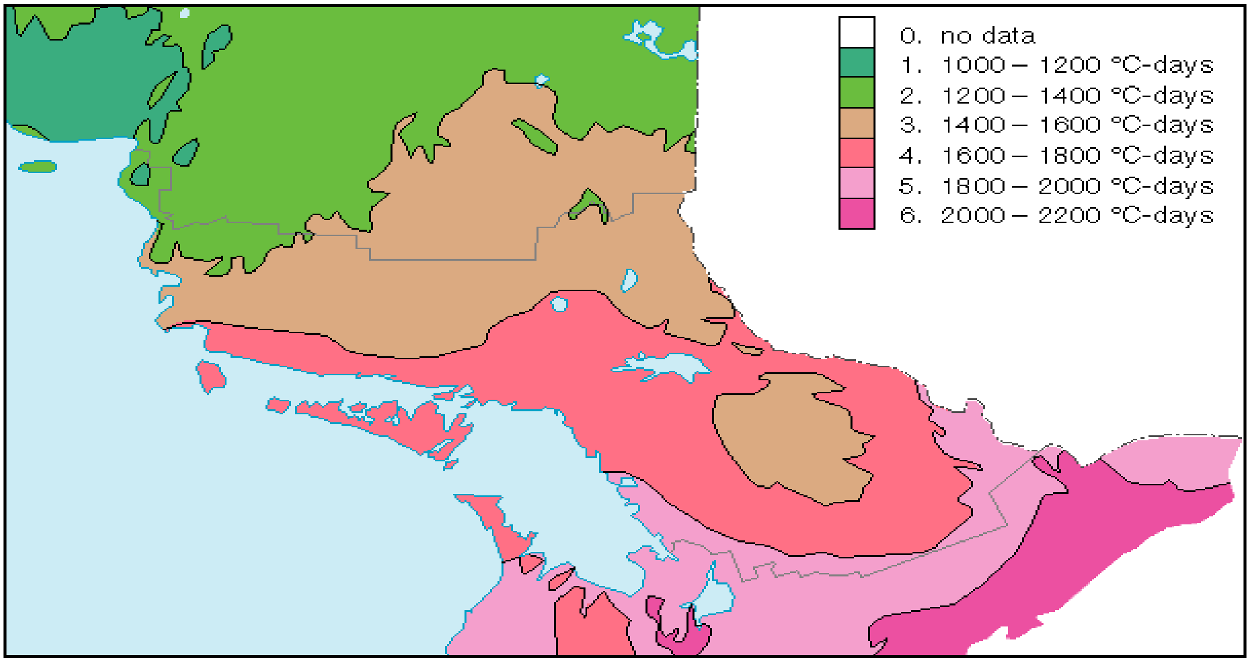
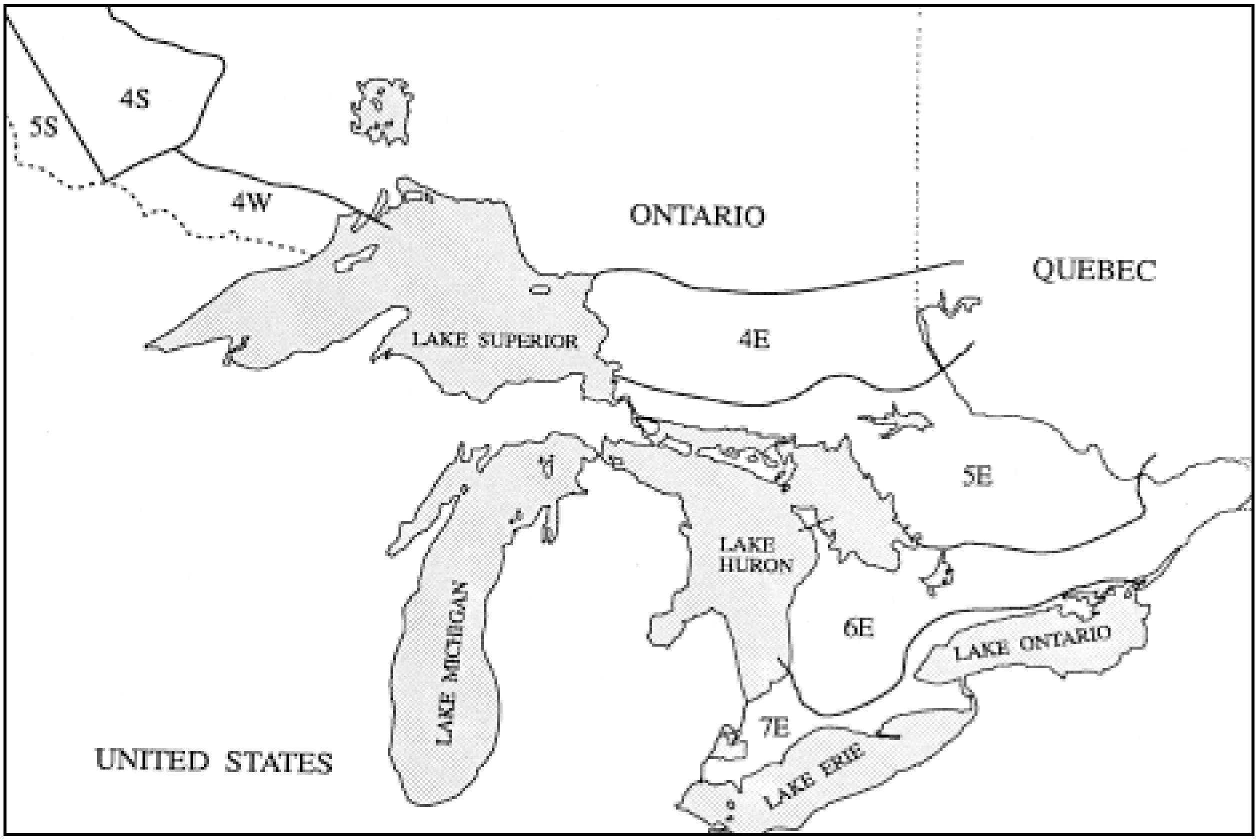


TABLE 3.0.1: Climatic data for the site regions of Ontario (*from:* MacKey *et al.* [1996])

Site Region	Mean Annual Temperature (°C)	Mean Length of Growing Season (days)	Mean Annual Precipitation (mm)	Mean 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 - 1,148	217 - 291
5S	1.4 - 2.8	182 - 190	557 - 712	243 - 287
5E	2.8 - 6.2	183 - 219	771 - 1,134	204 - 304
6E	4.9 - 7.8	205 - 230	759 - 1,087	198 - 281
7E	6.3 - 9.4	217 - 243	776 - 1,018	196 - 257

FIGURE 3.0.4: Site regions of Ontario that support species of the tolerant hardwoods working group (*from:* Hills [1959])



3.2 Soils

Field methods for describing soils can be found in the *Field Manual for Describing Soils in Ontario* (Ontario Centre for Soil Resource Evaluation 1993); the methods are based on those described by the Canada Soil Survey Committee (1987) and the Expert Committee on Soil Survey (1983).

Tolerant hardwood forests occur on two distinct zones in Ontario. The southern forests (those areas approximately south of the city of Barrie) occupy fertile, relatively deep soils, developed from Paleozoic shales and limestones, while those in the north occur on less fertile, relatively shallowsoils, mainly developed from Precambrian granites and gneisses. Most of the surface of this land has been moulded by moving continental ice sheets or is covered by glaciofluvial and lacustrine deposits and remains relatively unaltered as an assemblage of depositional landforms (Chapman and Putnam 1984).

In the southern zone, the bedrock surface has minimal topographic relief with the exception of the Niagara escarpment and the Dundalk upland (520 m above sea level [ASL]) and the Oak Ridges moraine (390 m ASL). A lower arch of Precambrian bedrock, called the Frontenac Axis, is exposed east of Kingston, while much of the Ottawa Valley is less than 60 m ASL. The overburden is usually deep, composed of calcareous soils; however, rock plains of dolomite and overburden is usually deep, composed of calcareous soils; however, rock plains of dolomite and limestone supporting relatively shallow deposits occur northward from Kingston toward Ottawa, and on Manitoulin Island, St. Joseph's Island and the Bruce Peninsula (Chapman and Putnam 1984).

In the northern zone, the relief is more pronounced; it consists of hills, ridges, and plains. The Algonquin Highlands is a peneplain (490 to 580 m ASL) dissected by valleys; local relief can vary by 15 to 60 m over very short distances. Glacial overburden is shallow, deficient in lime (low-base), with many rock outcrops. The valleys are often blocked by glacial debris and occupied by lakes.

Glaciation has created a complex configuration of moraines, spillways, drumlins, abandoned shorelines, and other deposits (Chapman and Putnam 1984). Because the glacial overburden was transported, deposited, and reworked by ice and water, the lithology of the parent soil materials may differ considerably from that of the underlying bedrock (Burger 1967).

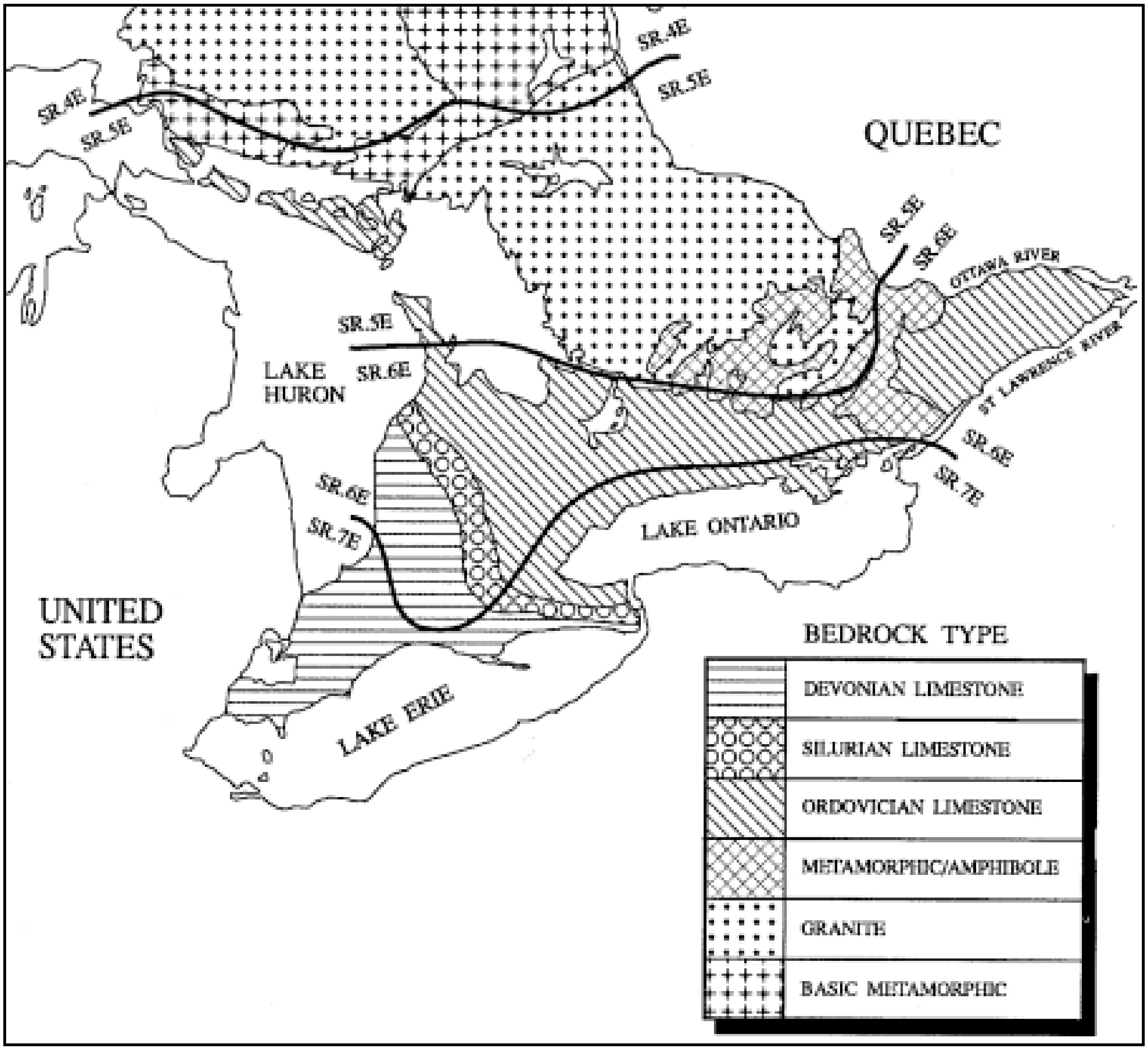
The soils of southern Ontario have developed on a wide range of geological materials and landforms (Taylor 1986). Textural variation of soils is often related to mode of deposition, which in turn is related locally to landform or elevation. For example, upland areas are usually ice deposited tills (such as moraines), and lower areas are frequently glaciofluvial valley-trains or lacustrine plains of sand or clay. The uniformly fine textured tills bordering the Great Lakes derive much of their silt and clay from these underlying lacustrine beds.

Chapman and Putnam (1984) partitioned southern Ontario into 55 physiographic regions based on landform. Of these regions, 52 occur in the intensively mapped southern Paleozoic portion of the province. They indicate areas of rugged till moraines (Dummer, Horseshoe), drumlin fields (Peterborough), and escarpments (Niagara), separated by undulating till plains and smooth clay and sand plains. Soil textural classes vary from sands (gravels to loamy, very fine sands) through loams (very fine sandy loams to loams) to clays (sandy clay loams to clays). The latter group of classes is usually calcareous and poorly drained (Taylor 1981, 1986).

To the north, on the Precambrian Shield, the soils have been less intensively mapped and are subdivided into only three areas by Chapman and Putnam (1984). Acid granites and gneisses have weathered to produce coarse-to-medium sands with very low base content. Some tills derived from such materials contain enough silt to be classified as “sandy loam”, but with a clay content so low that the term “silty sand” is more definitive. Some “basic” or base-rich Precambrian rocks such as basalt and metamorphic rocks such as amphibolite have base contents higher than granites but still much lower than limestone; these are considered to be low-base materials (Hills 1960). In the eastern part of this northern zone (near Renfrew), parent materials have been classified and mapped, including their depth-over-bedrock and moisture regimes (Burger 1971).

Over most of the Shield the layer of unconsolidated drift is less than three metres deep, but it is deeper in the moulded till ridges or drumlinoid land-forms. Clay deposits within the Precambrian Shield are derived from Paleozoic deposits transported from areas off the Shield. Soil profiles are useful in determining the potential productivity of land but must be interpreted locally in combination with relief, soil texture, local climate, vegetation, and management practices. Profile development involves changes in the upper portions of geologic materials of landforms and accumulation of organic residues. This weathered portion is most significant for biological production.

FIGURE 3.0.5: Bedrock geology of southern Ontario (*from*: Chapman and Putnam 1984; Hills 1959)



3.3 Predominant Sites

As stated above, Ontario can be divided into several physiographic zones according to climate (temperature and moisture) and landform (texture of geologic materials and mode of deposition). Vegetational succession has followed different patterns in each of these areas. In addition, within a given area, successional trends may vary with the type of disturbance, such as fire, wind, insects, logging, or land clearing.

The forest sites of Ontario have been variously described (using biotic and abiotic components), classified (in a comparative framework giving ranges of values), and evaluated (to provide production parameters) (Pierpoint 1986). This has given rise to the concept of “Site Region” (Hills l959), defined as a part of the land surface within which the response of vegetation to the features of landform follows a consistent pattern (FIGURE 3.0.4). Differences in such relationships among Site Regions are a reflection of the effect of regional macroclimate. Within a Site Region, therefore, specific plant successions occur on certain landform positions. Each region has a given potential biological production, and responds to specific forest practices in a predictable manner. The Site Region boundaries have been updated by Burger and Shidong (1988), and agree with the *Ecoclimatic Regions of Canada* developed by Zoltai (1986). MacKey *et al.* (1996) have examined Hills’ boundaries relative to their climate zonation for the province and have confirmed many of the climatic gradients established by Hills.

Species dominance and abundance in relatively undisturbed forests throughout the tolerant hardwood range are shown in TABLE 3.0.2, according to soil moisture regime (drier, fresh, wetter) and ecoclimate regime (hotter, normal, colder) (Hills l959). Although a sugar maple-yellow birch mixture is common on normal sites in Site Region 5E, it occupies hotter-fresh sites in Site Region 4E. Similarly, yellow birch is replaced by beech on fresh-normal sites in Site Region 6E.

Detailed information on site productivity in tolerant hardwood forests has been developed on a Regional basis using a variety of methods which vary by region.

- Site Regions 6E and 7E:

  Soil productivity and the suitability of species for certain soils are evaluated by OMNR using the Ontario Institute of Pedology’s system (Taylor and Jones 1986). Sites are classified based on the Ontario Soil Survey database (Pierpoint and Uhlig 1985), and data from plots that are stratified by site region, stand composition, and soil series map units. Site index classes are given for each soil series and surface texture class for 16 species, including sugar maple, white ash, red oak, black cherry and beech. Resource managers can use a guide that relates soil texture group and depth-to-mottling to site class and site index for each species. This information is relevant to even-aged stands only.

- Site Region 5E (South):

  In the southern portion of Site Region 5E, site evaluation has been done using physiographic features and a subjective productivity ranking. In local areas such as the former University of Toronto Forest near Dorset, the Hill’s system has been used (Hills and Brown l955). Williams (1965) rated sites for potential timber-quality production using physiographic parameters. He reported a maximum relative development for a range of species under “best known” conditions on a variety of landtypes.

TABLE 3.0.2: Characteristic forest species commonly occurring under least disturbed conditions in Ontario (*from*: Hills [1959])					
PHYSIOGRAPHIC SITE CLASS		SITE REGION			
		4E	5E	6E	7E
ECO-CLIMATE	MOISTURE REGIME	FOREST SPECIES COMMONLY OCCURRING			
Hotter	Drier	w, r, j Pine - w Birch - t, lt Poplar	**r Oak - w, r Pine (bur Oak)**	a Beech - e Hemlock r Oak - s, r Elm (lt, t Poplar, Juniper)	b, r, sc, sw Oak - Chestnut - p, sb Hickory - Butternut w Pine (Juniper)
Hotter	Fresh	*h, r Maple - y Birch w Pine - b Fir - w Spruce*	*h Maple - r Oak a Beech - e Hemlock*	w, r Oak - sb Hickory (r Elm, Butternut)	Tulip - Walnut - w, r Oak - mn, pn Hickory blue, w Ash, Butternut
Hotter	Wetter	*y Birch - w Cedar (a Elm)*	*a Elm - b Ash - r Maple w (r) Spruce - e Hemlock*	*h, s, r Maple - y Birch - Walnut - b Cherry*	*Sycamore - Tulip a, s Elm - Ash - y Birch*
Normal	Drier	**w, r, j Pine (h, r Maple)**	**w, r, Pine - e Hemlock (a Beech, w Ash)**	**h, r Maple - w, r Oak - w Ash - a Elm**	r, w Oak - sb, pn Hickory a, r Elm (Juniper)
Normal	Fresh	**b Fir - w Spruce - w (r) Pine (w Birch - t Poplar)**	**h Maple - y Birch e Hemlock - w Pine (w Spruce - b Fir)**	**a Beech - h Maple - r Oak - e Hemlock**	**h Maple - a Beech - w, r Oak - sb Hickory**
Normal	Wetter	*b Fir - w, b Spruce*	b Ash - r Maple w Pine - w Spruce - b Fir	Hemlock - y Birch a, s Elm, w Cedar, b Fir	**sw, p Oak - r, g, b Ash - s, a Elm - b Hickory**
Colder	Drier	*b Fir - w Cedar*	*w Spruce - b Fir - w Pine*	w (r) Pine w Ash - a, r Elm (w Cedar)	*e Hemlock - a Beech - y Birch - w Pine*
Colder	Fresh	**b Spruce - a Larch**	*b Fir - w Spruce - w Pine (w Cedar, w Birch)*	*w Spruce - b Fir*	**a, s Elm - b Ash - sw Oak - r Maple**
Colder	Wetter	*(locally open) b Spruce - a Larch*	b Fir - b (w) Spruce - a Larch	*b Fir - b, w Spruce a Larch*	*b, w Spruce - b Fir s, r Maple - y Birch*

Species characteristic of regional forests are hyphenated (e.g. r Oak, - s, r Elm). Additional species are characteristic of specific sites. Abbreviations for species are shown in APPENDIX A.

Parentheses indicate associations and species that are common but are not indicators for all components of the site class. Proportionate distribution of site class within each site region: **High**, Moderate, *Low*

- Site Region 5E (North):

  The northern portion of Site Region 5E approximates the commercial limit of the range of tolerant hardwoods. Here, the occurrence and growth of the 5E species depends on local site conditions.

General Site Types that are amenable to management of tolerant hardwood forests include:

- a “fractured” site complex of relatively shallow ablation moraine till, often characterized by repeating sequences of ridge-and-valley terrain, with dry ridges, wet valleys, and fresh to moist slopes influenced by a telluric water table. Middle and lower slopes are biologically productive but difficult to manage because of terrain configuration.

- a drumlinized landscape in which relatively deep-soiled moulded till ridges, shallowly capped with ablation till, occur sporadically within the fractured site complex. The elevated plateaus are characterized by fresh-to-moist soils containing water-retentive compacted layers. Frequently covered by pure hardwoods, such sites offer good management opportunities because of flat but productive land.

- lacustrine plains of waterlaid fine sands, silts, and clays, often with fresh-to-moist moisture regimes, and frequently dominated by mixed forest cover. Productivity is often related to depth-to-mottling in the soil. Imperfectly drained sites are usually not suitable for tolerant hardwoods due to restricted rooting volume.

Sites that can produce high quality tolerant hardwoods have the following soil characteristics:

- Moisture:

  Best conditions are fresh to moist, with sugar maple, beech, and red oak occupying fresh (moisture regime [MR] 1-3) while yellow birch and hemlock do well in very fresh to moist (MR 3-5) conditions. White ash, basswood and black cherry occupy sites with an intermediate moisture regime. Neither dry nor wet conditions permit high-quality production.

- Texture:

  Silty sands and sandy loams are good, and fine sands and silt loams may be adequate if moisture regime is satisfactory. Coarse sands and heavy clays are not suitable.

- Organic content:

  Well-decomposed and well-incorporated humus materials are required for proper nutrition of hardwoods. Hemlock-dominated sites accumulate raw humus and form hardpan deposits that are not suitable for hardwoods. Succession to hardwoods may be adversely affected by soil podzolization.

- Chemistry:

  Most hardwood species perform best when soil pH is in the range of 5.5 to 7.5. More acid conditions favour hemlock and yellow birch. Strongly acid or alkaline conditions are unfavourable due to effects on nutrient availability or to potential toxic conditions (e.g. soluble aluminum).

- Rooting Depth:

  Soils with restricted rooting volume caused by shallow soil deposition or a high water table are unsuitable. An effective depth of at least one metre is required for adequate growth potential. Red oak may persist on shallow ridges and yellow birch may grow on very moist soils (due to rooting character), but neither situation is highly productive for these species.

Site suitability is also influenced by non-soil factors; of which the most important factor is:

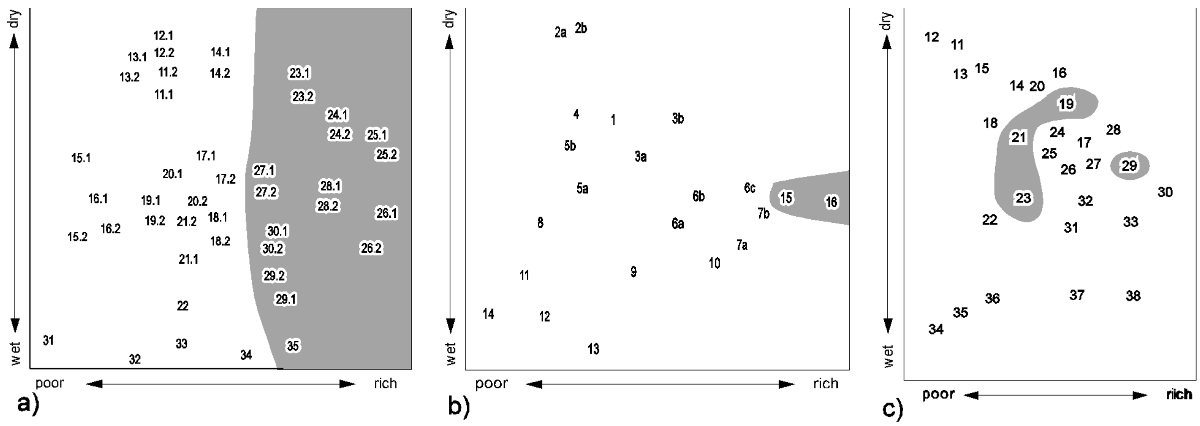
- Microclimate:

  Hardwoods may be restricted to south aspects on slopes in the northern transition zone (i.e. in the Algoma Forest Section) but drought may limit hardwood growth on such sites in other northerly forest sections. Hardwoods on exposed ridges may experience winter sunscald damage, and lower slopes that restrict air drainage may cause frost damage.

3.4 Ecosite Classification

Ecosites are classification units that reflect the interactions of vegetation, climate, landforms, soils and the impacts of human activities. Ecosite classifications have been developed for the Central Region (Chambers *et al.* 1997), the Northeastern Region (McCarthy *et al.* 1994), and the Northwestern Region (Racey *et al.* 1996). Forest ecosystem classification is still being developed in southern Ontario (Lee *et al.* 1996). Ordination diagrams for ecosites in each region (FIGURE 3.0.6) illustrate the relative positions of ecosites along axes of fertility and moisture. The highlighted areas in the ordination diagrams identify the ecosites where tolerant hardwoods occur. Ecosite numbers are unique for each region. A listing of the *Field Guides* that contain detailed ecosite fact sheets are presented in APPENDIX B.

FIGURE 3.0.6: Ordination diagrams for tolerant hardwood ecosites in 3 regions of Ontario



Ordination diagrams for a) central Ontario, b) northeastern Ontario and c) northwestern Ontario, highlighting ecosites in which tolerant hardwoods, mid-tolerant hardwoods and/or hemlock dominate.

Following is a listing of the ecosites presented in FIGURE 3.0.6, with general descriptions of vegetation, distribution and climate:

Central Ontario Ecosites

ES 23.1 Red Oak-Hardwood on dry to moderately fresh soils.
ES 23.2 Red Oak-Hardwood on fresh to moist soils.
ES 24.1 Sugar Maple-Red Oak-Basswood on dry to moderately fresh soils.
ES 24.2 Sugar Maple-Red Oak-Basswood on fresh to moist soils.
ES 25.1 Sugar Maple-American Beech-Red Oak on dry to moderately fresh soils.
ES 25.2 Sugar Maple-American Beech-Red Oak on fresh to moist soils.
ES 26.1 Sugar Maple-Basswood on dry to moderately fresh soils.
ES 26.2 Sugar Maple-Basswood on fresh to moist soils.

Ecosites 23 to 26 are hardwood-rich vegetation communities. Sugar maple typically dominates the overstory, with associated species including basswood, beech, red oak, black cherry, ironwood and white ash. Regeneration of all of these species is often present in these ecosites, with sugar maple regeneration being dominant. Vegetation communities often reflect calcareous conditions characteristic of the marble belt in the southern part of the region, and the limestone-based soils of Manitoulin and St. Joseph's Islands (Ecosites 26 and 24). Many understory species, including spring ephemerals found in these ecosites, are typical of more southern locales. A high number of growing degree days and warmer winters are typical of these ecosites (***see*** TABLE 3.0.3)

ES 27.1 Sugar Maple-White Birch-Poplar-White Pine on dry to moderately fresh soils.
ES 27.2 Sugar Maple-White Birch-Poplar-White Pine on fresh to moist soils.
ES 28.1 Sugar Maple-Eastern Hemlock-Yellow Birch on dry to moderately fresh soils.
ES 28.2 Sugar Maple-Eastern Hemlock-Yellow Birch on fresh to moist soils.
ES 29.1 Sugar Maple-Yellow Birch on dry to moderately fresh soils.
ES 29.2 Sugar Maple-Yellow Birch on fresh to moist soils.

Ecosite 27 is a mixture of tolerant and intolerant species. White pine may be present as an associate. Tall hardwood shrubs including beaked hazel and mountain maple are part of a typically diverse understory, with regeneration of sugar maple being dominant.

Ecosites 28 and 29 are dominated by sugar maple, yellow birch and/or eastern hemlock.

Ecosite 28 is characteristic of the Algonquin Highlands. The understory is dominated by regeneration of sugar maple, with hardwood shrubs including hobblebush and striped maple. High precipitation (3 months prior to the growing season) and high elevation (greater than 350 m above sea level) are typical of these ecosites (***see*** TABLE 3.0.3).

Ecosite 29 has a lower minimum winter temperature and fewer growing degree days than Ecosite 28 (***see*** TABLE 3.0.3). Ecosite 29 is typically found in the Algoma Highlands and other parts of Site Region 4E, with an understory of ground hemlock, tall hardwood shrubs, and regeneration of sugar maple, balsam fir and yellow birch.

ES 35 Lowland Hardwoods on very moist to wet soils, in flats or pockets, telluric slopes and fluvial-sites.

A number of species-rich tolerant hardwood stands adjacent to waterways, on telluric slopes and in association with black ash swales occur in this ecosite. These ecosites are often classed as an "Area of Concern" (AOC).

Northeastern Ontario Site Types

ST 15 Tolerant Hardwood Mixedwood
ST 16 Sugar Maple-Yellow Birch

Site Type 15 is a transitional Great Lakes-St. Lawrence Forest Region type occurring on ridges, plateaus or hilltops in Site Region 4E. Red maple is present along with a mixture of intolerant hardwoods and boreal conifers. The understory is typical of a boreal mixedwood stand, with tall hardwood shrubs including mountain maple and beaked hazel. Regeneration of red maple and balsam fir is also present.

Site Type 16 occurs on similar sites as ST 15, but more than 50 per cent of the basal area is in sugar maple and yellow birch. Tall hardwood shrubs (mountain maple, beaked hazel) and regeneration of sugar maple and yellow birch are present in this ecosite.

TABLE 3.0.3: Summary of climatic data (means) and site region allocation for central Ontario tolerant hardwood ecosites							
Ecosites	Minimum Temperature *coldest month* (°C)	Growing Degree Days *total growing season*	Precipitation *3 months prior to growing season* (mm)	Elevation *above sea level* (m)	Average Latitude (° North)	Site Region Allocation 4E (%)	Site Region Allocation 5E (%)
23.1	-18.4	1,687.9	203.9	310	45.4	0	100
23.2	-18.5	1,701.2	205.2	313	45.4	0	100
24.1	-18.7	1,703.9	198.3	343	45.1	0	100
24.2	-19	1,757.4	186.1	263	45.3	0	100
25.1	-18.7	1,662.2	213.1	339	45.5	0	100
25.2	-18.7	1,704.2	203.3	292	45.5	3	97
26.1	-17.9	1,748.2	196.3	262	45.3	0	100
26.2	-19.1	1,738.2	193.8	251	45.6	0	100
27.1	-19.7	1,602.9	193.3	299	46.3	21	79
27.2	-19.4	1,639.0	193.7	304	46	9	91
28.1	-19.8	1,583.4	204.6	382	45.8	0	100
28.2	-19.7	1,612.2	201.3	366	45.7	1	99
29.1	-21.3	1,434.3	186.1	355	47.1	100	0
29.2	-21.0	1,475.9	191.4	356	46.8	84	16
30.1	-20	1,567.8	201.9	381	45.9	0	100
30.2	-20	1,579.2	199.5	365	45.9	7	93
35	-19.1	1,647.8	189.9	269	46.1	29	71

Northwestern Ontario Ecosites

Patches of tolerant hardwoods (red maple, yellow birch and sugar maple) occur within larger mixedwood ecosites in the Northwest. Thus, specific information on understory and tree species regeneration is lacking where these species occur.

ES 19 Hardwood-Fir-Spruce Mixedwood on fresh, sandy-coarse loamy soils.
ES 21 Fir-Spruce Mixedwood on fresh, coarse loamy soils.

Yellow birch, red maple and sugar maple stands occur in these ecosites in Site Regions 4S, 4W and 5S.

ES 23 Hardwood-Fir-Spruce Mixedwood on moist, sandy-coarse loamy soils.
ES 29 Hardwood-Fir-Spruce Mixedwood on moist, sandy-coarse loamy soils.

Yellow birch and red maple stands occur in these ecosites in Site Regions 4S, 4W and 5S.

TABLE 3.0.4 provides an expert-based cross-tabulation of regional ecosites. It was developed by comparing overstory, understory and soil features provided on the regional factsheets.

TABLE 3.0.4: Ecosite equivalency between regions*

CENTRAL ONTARIO	NORTHEASTERN ONTARIO	NORTHWESTERN ONTARIO
ES 23, 24, 25, 26, 28	-	-
ES 27	ES 15	-
ES 29	ES 16	-
-	-	ES 19, 21, 23, 29

* Equivalencies shown in this table are approximations only, due to variation of vegetation and soils between sites.

4.0 SILVICS

4.0 Silvics

by Harvey Anderson, Brenda Chambers, James Rice and Barb Merchant

The silvical characteristics of each species in the tolerant hardwood forest define that species' capacity to reproduce, establish and develop within the various site types in Ontario. More importantly, the silvical characteristics indicate a species' biotic potential to react to and perform following forest disturbances and timber management activities. Prescribed harvesting systems must harmonize these features. The management methods used for the various species or species groups will differ, each capitalizing on the intrinsic characteristics of the species to optimize the production of forest commodities and the protection of other resource values.

The following material has been gathered from a wide range of sources, many of which are cited in other appropriate sections of this guide. General overviews for habitat, reproduction, establishment and development can be found in Fowells (1965), Burns and Honkala (1990), Treidl (1978), Grisez (1975), Trimble (1975), OMNR (1983), Anderson *et al.* (1990) and Farrar (1996).

Further information on damaging agents, including field guides, can be found in Myren and Dorworth (1986), Anderson *et al*. (1990), Basham (1991), Gross *et al.* (1992), Myren (1994), Myren *et al.* (1994) and Davis and Meyer (1997).

4.1 Sugar Maple

4.1.1 Habitat

- Northern limit parallels the 2° C mean annual isotherm; growing season can be as short as 30 days in some locations

- Grows with as little as 500 mm of precipitation if majority of the precipitation occurs during the growing season

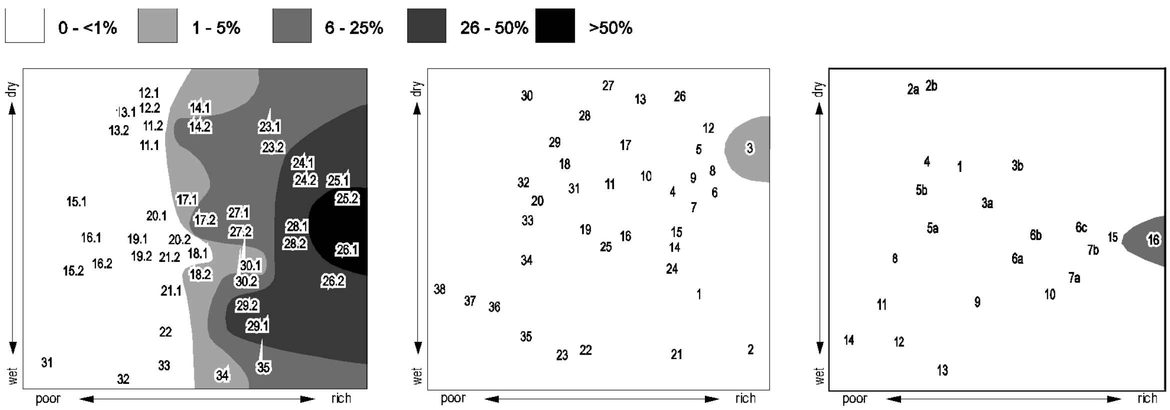
- Predominant species in eastern mesophytic late-successional forest; well adapted to the cool microclimate of mature forests

- Mature trees are potentially large, growing to 100 cm or more (DBH) and 30 m in height, often to ages in excess of 300 years

- Reproduces aggressively and may occur in pure or mixed, even- or uneven-aged stands on relatively fertile, fresh, well-drained upland sites (MR 1 to 3) (***see*** FIGURE 4.0.1). In northwestern and northeastern Ontario it is restricted to fresh, fertile sites. In central Ontario, it may also occur on dry to moist sites, but it is usually absent from infertile sites

- In uneven-aged stands, is frequently mixed with beech on fresh sites and yellow birch on moist sites.

FIGURE 4.0.1: Mean per cent cover of sugar maple canopy trees by ecosite and in relation to soil moisture and fertility based on FEC plots sampled in Ontario. Numbers indicate ecosite types. Refer to Section 3.4 “Ecosite Classification” for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

b) Northwestern Ontario vegetation types (2,139 FEC plots)

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

- In even-aged stands, it is often mixed with less shade-tolerant species such as black cherry, white ash, basswood and yellow birch

- In cool areas with more than 760 mm of annual precipitation, may occur on poor, exposed sites, but usually does not thrive there

- Performs best on sandy loams, loamy sands and silt loams (often melanized), with a pH greater than 5.5 in upper soil horizons, yet will commonly grow in more acid soils and soils ranging in texture from sandy to fine loamy/clayey (***see*** FIGURE 4.0.2)

- Log yield and quality increase as soil fertility improves within suitable moisture regimes (MR 2 to 3).

4.1.2 Reproduction

- Species is monoecious; flowers are either perfect or unisexual, with a male to female ratio of 50:1

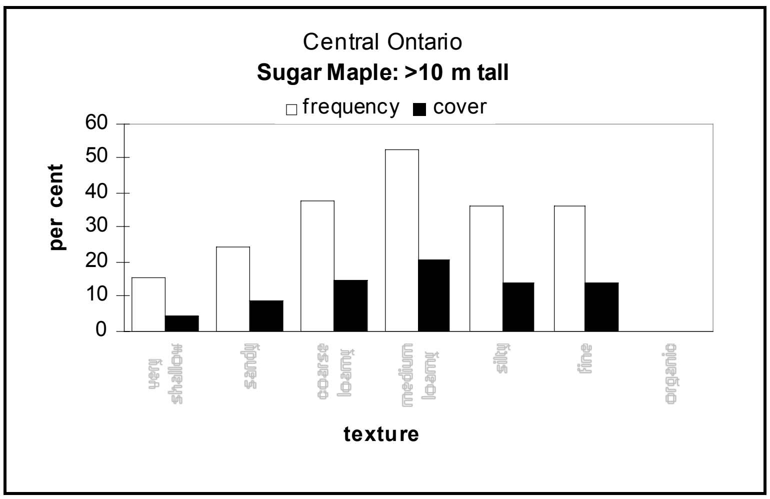
- Flowers appear with unfolding leaves, usually in early May

- Fruit is a double-winged samara, ripening in twelve weeks and dispersing two weeks later, usually prior to leaf fall

- Samaras are effectively wind-dispersed for a distance of two to three tree-heights and up to 300 m in a strong wind

- Often one seed-pod of a pair is empty; occasionally both are sterile (this condition is known as “parthenocarpy”).

FIGURE 4.0.2: Frequency and per cent cover of sugar maple >10 m tall from 1,539 FEC plots in Central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that had sugar maple. The right (black) bar indicates the mean per cent cover of sugar maple across all plots within a texture class



- Flower crops and seed crops are closely related (and therefore predictable)

- Seed production tends to increase with tree diameter

- Significant seed production begins at about age 40 to 60 years

- Mature trees produce some seed most years, with good crops every two to five years

- Reproduces easily by stump sprouts; occasionally by layering

- Sprouting is most vigorous and long-lived in small stumps (less than 15 cm DBH)

- Sprouts usually grow faster than seedlings in the first year, often showing an extended growing season

- Seedling sprouts and those from small stumps have potential to produce high-quality stems if properly tended

4.1.3 Establishment

- Seed has embryo dormancy and requires cold stratification

- Seed germinates at low temperatures (1° C), often before snow is completely melted in the spring; seed is often covered by forest litter

- Germinative capacity is moderate (39 per cent); some seed may remain viable into the second year

- Reproduces easily on undisturbed litter; the large seed produces a vigorous radicle which allows easy penetration of the matted leaf layer into the soil

- Very tolerant of shade; seedlings can persist for several years in 5 per cent of full light and can produce modest growth at 13 per cent of full light

- Early survival of young germinants is enhanced by shade, often resulting in prolific advanced growth of small seedlings—even under a full overhead canopy

- Dense seedling populations show high turnover rates under heavy shade (often with 50 per cent mortality in the first three years following germination)

- Older seedlings persist under heavy shade but exhibit slow growth; seedlings 50 cm tall at age 25 years with annual increments as low as 1 cm and saplings 2.5 cm DBH at age 50 years are not rare

- Does not usually reproduce aggressively by seed on abandoned, cleared land

- Species may reproduce aggressively by seedling sprouts in excessively opened stands (less than 9 m^2/ha of basal area) from seedlings damaged during harvest operations—producing essentially even-aged regeneration.

4.1.4 Development

- Usually leafs-out earlier than associated species, with understory trees preceding those in the overstory

- Height growth and radial growth commence with leaf expansion (usually in early May)

- Height growth is determinate; 85 per cent of height growth is complete by the end of June (6 weeks) and it ceases by early August (12 weeks); radial growth is 80 per cent complete by the end of July (11 weeks) and ceases in late August (14 to 17 weeks)

- Height growth rates are highest for juvenile trees, averaging 30 cm per year under moderate stocking levels. Height growth rates decline with increasing tree age and become negligible by age 90-110.

- Self-pruning is good with sufficient stocking but little merchantable length is added after trees reach approximately 45 cm DBH

- Exhibits slow-to-moderate but persistent diameter growth; in unmanaged stands, mature trees may grow an average of 2.5 cm in ten years

- Shows remarkable response to release (i.e. an *elastic* species) both in height and diameter growth of immature trees; annual height increments of 90 cm and ring widths of 10 mm are possible (but not common) in relatively young trees that have not been suppressed for long periods of time (10 to 20 years)

- Even severely suppressed trees respond well to release and can show improvement in size and quality

- Excessive release of suppressed trees up to 20 cm DBH often results in the development of epicormic branches from dormant buds; these branches often die within eight years, provided stand density increases

- Excessive release may promote sunscald, top decline and persistent stem forks

- The root system is relatively deep and branching on well-drained soils; trees are relatively resistant to windthrow except on thin soils or shallow-capped drumlin landforms

- Periodicity of root growth is independent of top growth; it occurs in surges throughout the growing season; root grafts are common within the species

- Unmanaged, uneven-aged forests, even on the best sites, are characterized by a great variation in stem defect and quality

- Ease of reproduction, shade tolerance and response to disturbance promote uneven-aged stands and make species amenable to the single-tree selection silvicultural system

- Even-aged stands may be managed as such or may be converted to uneven-aged stands as they approach maturity.

4.1.5 Damaging Agents

- Decay losses caused by trunk and butt infections are serious in unmanaged stands. In Site Regions 4E and 5E, cull averages 30.4 per cent of gross merchantable volume and ranges from 22 per cent at 33 cm DBH to 40 per cent at 60 cm DBH. Brown stain accounts for 80 per cent of the defect volume (Basham and Morawski 1964; Morawski *et al.* 1958)

- The high defect values at young ages are unique to maple and reflect the slow growth of suppressed trees (Basham 1991).

- South of the Shield, in Site Region 6E (e.g. Grey County), 65 year old trees exhibit 5 per cent cull compared to 22 per cent in Site Region 5E. The lower values are associated with faster growth rates and a lower incidence of stain in trees (Basham 1973, 1991)

- Annual volume losses caused by decay fungi average 308,000 m^3 (***see*** TABLE 4.0.1).

TABLE 4.0.1: Estimated annual volume loss (m^3 x 1,000) 1982 to 1987, caused by destructive agents in the tolerant hardwood forest in Ontario (*from:* Gross *et al*. [1992])

AGENT	SPECIES	VOLUME LOSS	MORTALITY	TOTAL LOSS
forest tent caterpillar	sugar maple	29.7		29.7
	yellow birch	6.0		6.0
gypsy moth	red oak	88	144	232
dieback	sugar maple		602	602
	red oak		39	39
decay	yellow birch	159		159
	sugar maple	308		308
	ash spp.	128		128
	red oak	11		11
	beech	32		32
	black cherry	1		1
	basswood	2		2

- *Inonotus glomeratus* (Peck) Murrill[1] accounts for about one third of infections and volume loss and together with *Armillaria mellea* (Vahl ex Fr.) Kummer and *Pholiota spectabilis* (Fr.) Kummer, represents more than 50 per cent of all cull

- Parasitic fungi that can kill maples include cankers (e.g. *Eutypella parasitica* Dav. & Lor. and *Nectria galligena* Bresad.) and sapstreak disease (*Ceratocystis coerulescens* (Munch) B.K. Bakshi)

[1] Scientific names are used in the text for organisms lacking unique common names. Scientific names given here are widely used operationally, but periodic taxonomic revisions are made as genetic relationships of organisms are clarified. Refer to Myren *et al.* (1994) concerning disease organisms.

- Defoliation by leaf-feeding insects, primarily forest tent caterpillar (*Malacosoma disstria* Hubner), occurs cyclically and not only reduces growth (29,700 m^3 annually from 1982 to 1987) of the host species, but also depletes food reserves which in the case of successive infestations, may result in mortality (***see*** TABLE 4.0.1)

- Stem quality degradation and tree mortality caused by breakage are associated with attacks by sugar maple borer (*Glycobius speciosus* Say.). The larval stage of this insect tunnels in the cambial zone of the tree

- Significant cyclical population increases of red-backed voles often result in sapling mortality due to basal stem girdling. This damage is most noticeable in winters with higher than average snow depths

- Man-made damage, related to sap-tapping operations and poorly organized stand harvesting and tending procedures, reduces the quality of residual stems. Wounds serve as infection courts for insects and diseases resulting in both volume and value losses (Love *et al.* 1972)

- Abiotically-induced damage is frequently associated with climate (i.e. frost crack, sunscald, ice glaze breakage and bud killing). The resulting wounds provide infection courts for fungi, damage tree form and reduce potential merchantable length because of forking

- Maple decline (characterized by crown dieback, loss of vigour and frequently, tree death) is of unresolved origin. It is often associated with insect defoliation and climatic stress.)

- Extensive damage to sugar maple caused by pear thrip (*Taeniothrip inconsequens*) defoliation has recently occurred in the eastern United States.

4.2 American Beech

4.2.1 Habitat

- Northern range limit closely parallels the -12° C mean January isotherm; can withstand cold temperatures but is prone to frost crack

- Is mesophytic, occurring in areas having greater than 635 mm of annual precipitation

- Can reproduce aggressively in undisturbed upland sites; forms a dominant member of moist late-successional forest communities

- Occasionally forms pure stands; more often found in uneven-aged mixtures with sugar maple, yellow birch and hemlock

- A long-lived tree, reported to reach ages of 400 years, but typically not exceeding 250 years due to stem breakage associated with internal decay

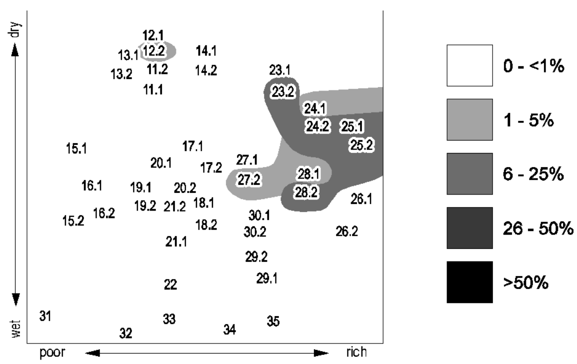
- Commonly grows to 60 cm DBH and 27 m in height

- Grows best on fertile, well-drained fresh soils, especially loamy soils with high humus incorporation. Also found on sandy to fine loamy and clayey soils

- In central Ontario it is found on ecosites that are moderately fertile to rich and fresh to moderately fresh (***see*** FIGURE 4.0.3)

- Adapts to poorer, shallow sites if moisture regime is fresh enough (MR 1 to 2), but vigour and quality usually decline (***see*** FIGURE 4.0.4)

FIGURE 4.0.3: Mean per cent cover of beech canopy trees by ecosite and in relation to soil moisture and fertility from 1,539 FEC plots in Central Ontario. Numbers indicate ecosite types. Refer to Section 3.4 "Ecosite Classification" for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

4.2.2 Reproduction

- Species is monoecious, with unisexual flowers

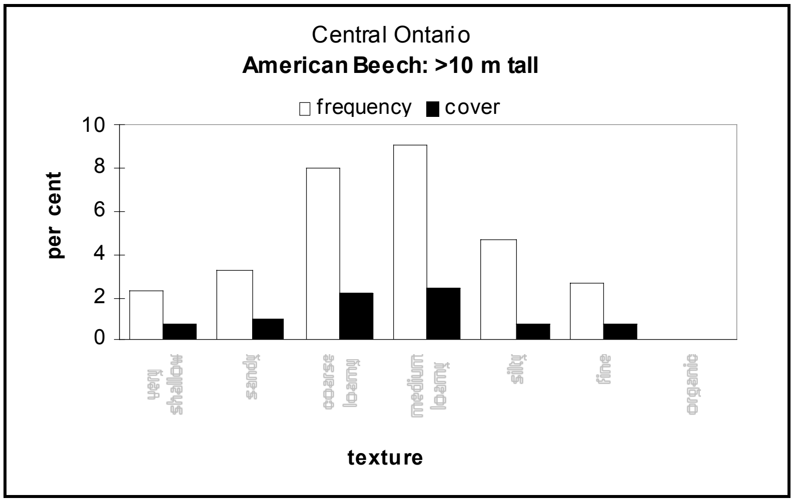
- Flowers appear in early May during period of leaf expansion

- Seed ripens between September and November; burs open to release seed with first heavy frost

- Large quantities of seed (mast) may be consumed by bears prior to and deer subsequent to, dispersal

- Dispersal usually restricted to vicinity of parent tree (one tree-height distance) because seeds are heavy; may be transported by animals

FIGURE 4.0.4: Frequency and per cent cover of American beech >10 m tall from 1,539 FEC plots in Central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that had sugar maple. The right (black) bar indicates the mean per cent cover of sugar maple across all plots within a texture class



- First seeds to fall may be aborted or wormy
- Dispersal complete within two weeks; empty burs remain on tree over winter
- Individual trees are consistent in seed production ability
- Trees bear seed adequately beginning at age 40 to 60 years
- Good seed crops occur every two to three years; light crops occur in intervening years
- Sprouts well from stumps up to 10 cm in diameter; sprouts from larger stumps are often short-lived
- Dense thickets of root suckers may surround older trees; few develop into good trees due to lack of an independent root system
- Can occasionally reproduce by layering.

4.2.3 Establishment

- Seed exhibits embryo dormancy requiring cold stratification; germinates best at approximately 15° C; no delayed germination
- Germinative capacity is usually high (for sound seed), but seed is susceptible to drying

- Species has no difficulty establishing itself on undisturbed hardwood litter because of high vigour of germinant radicle

- Requires adequate moisture in soil or organic layer, but germinates poorly on excessively wet sites

- Very shade-tolerant, though apparently less so on poorer sites; can grow moderately well in 13 per cent of full light

- Seedlings develop better beneath a moderate canopy or in small protected openings than in full light or clearcut situations—probably due to drying effect on exposed soil

- May form dense seedling stands under full shade because of its shade tolerance and relative freedom from deer browsing

- Usually over-topped by associates and intolerant species in conditions of low stocking

- Often performs better on north aspects (which promote moisture conservation).

4.2.4 Development

- Radial growth begins with full expansion of leaves and continues until late August, depending strongly on soil moisture availability; diameter growth is usually complete in 15 weeks

- Height growth is determinate and is 90 per cent complete by the end of June; shoot tips may abort after extension of pre-formed leaves

- Saplings can withstand intensive shading and recover when released (i.e. species is *elastic*); severely suppressed trees are often flat-topped and crooked

- Rated "slow" in relative DBH growth rate; often averages 2.5 cm in ten years for mature trees in fully stocked stands and double that rate in "partially cut" stands

- Natural pruning is adequate in well-stocked stands

- Prone to sunscald and epicormic branching after exposure caused by heavy cutting (greater than 50 per cent of basal area removed), especially in trees less than 10 cm DBH

- Root system is wide-spreading and moderately deep; often remains shallow where soil moisture is adequate; species is relatively windfirm

- Root grafting is common; root suckers are common in overmature specimens

- Bark is thin and vulnerable to fire, frost, bear and mechanical injury

- Shade tolerance and ease of establishment make this species suitable for uneven-aged management systems.

4.2.5 Damaging Agents

- Potentially the most damaging (lethal) agent is the beech bark disease complex, initiated by primary feeding-injury of Beech scale (*Cryptococcus fagisuga* Lindeman), followed by secondary infection of *Nectria coccinea* var. faginata (Lohm, Wats and Ay). This disease is not yet widespread in Ontario but has caused much deterioration of beech in the United States and eastern Canada (Myren 1994)

- Beech is a defective species in terms of decay, but less so than sugar maple at immature stages and less so than yellow birch at all stages of maturity. Two-thirds of defect in beech involves brown stain (Basham and Morawski 1964)

- Of the remaining defect, about 16 per cent is caused by white spongy rot and 14 per cent is caused by yellow-brown stringy rot

- *Inonotus glomeratus* (Peck) Murrill (a yellow-brown stringy rot) causes 36 per cent of all decay infections in beech and, together with *Fomes igniarius* (L. ex Fr.) Kickx (a white spongy trunk rot), *Pholiota adiposa* (Fr.) Kummer and *Armillaria mellea* (yellow-brown stringy trunk and butt rot), constitutes 66 per cent of all infections and decay (Basham and Morawski 1964). Average cull in sawlogs in the Algonquin Ecological Section is estimated to be 35 per cent (Morawski *et al.* 1958)

- Annual volume losses in beech caused by decay fungi averaged 32,000 m^3 per year from 1982 to 1987 (***see*** TABLE 4.0.1)

- Beech is infected by canker diseases caused by *Strumella* spp. and *Nectria galligena*

- Beech foliage is favoured food for saddled prominent (*Heterocampa guttivitta* (Walker) Bres.) and may be part of the host preference of Bruce spanworm (*operophtera bruceata* Hlst.)

- Species is thin-barked and very susceptible to injury from logging, fire, sunscald and animal feeding

- Bark is consumed as food by beaver, black bear, squirrels, porcupine and voles

- Subject to frost crack, often related to an internal wetwood condition; may be killed by severe cold following a period of drought

- Seeds are consumed in quantity by black bear, deer and various birds and rodents; this may affect regeneration potential.

4.3 Yellow Birch

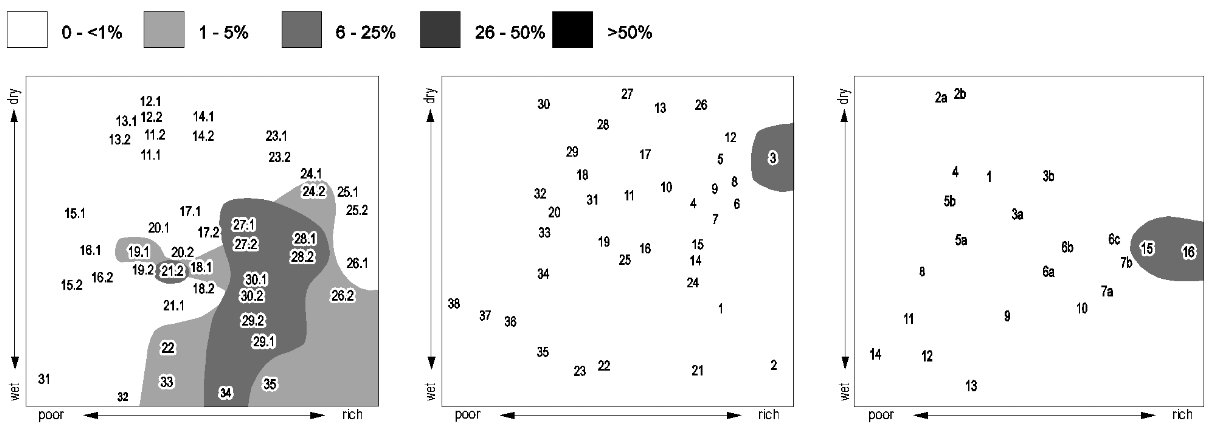
4.3.1 Habitat

- Occurs south of the mean July 16° C isotherm in areas with an effective growing season longer than 160 days

- Extends north to the mean January -15° C isotherm west of the Great Lakes, but only to the mean January -12° C isotherm in the east

- A prominent member of the successional forests of eastern North America. In central Ontario it is found in a wide range of ecosites (***see*** FIGURE 4.0.5a) with the highest per cent cover on fresh to wet, moderately fertile to rich sites. In northwestern Ontario (FIGURE 4.0.5b) it is restricted to vegetation type 3 (moderately dry, rich sites). In northeastern Ontario (FIGURE 4.0.5c) it is restricted to site types 15 and 16 (fresh, rich sites).

FIGURE 4.0.5: Mean per cent cover of yellow birch canopy trees by ecosite and in relation to soil moisture and fertility from FEC plots sampled in Ontario. Numbers indicate ecosite types. Refer to Section 3.4 "Ecosite Classification" for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

b) Northwestern Ontario vegetation types (2,139 FEC plots)

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

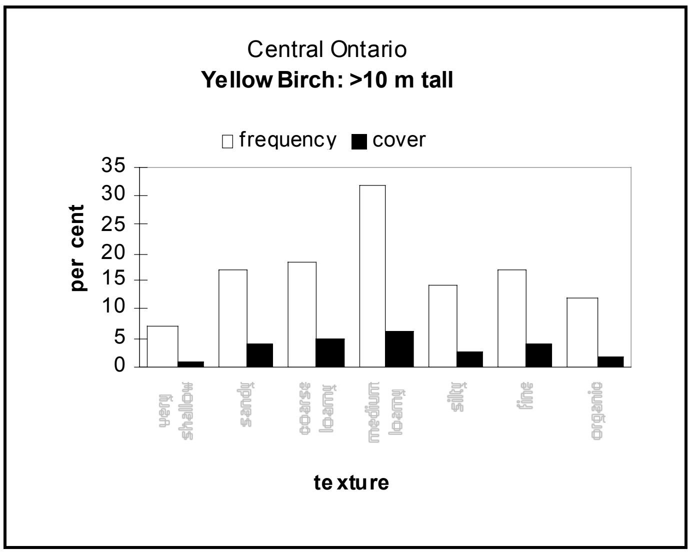
- Develop as potentially large trees, 100 cm or more DBH and 30 m in height, often reaching ages in excess of 300 years

- A successional species; tends to be replaced by more shade-tolerant species (e.g. sugar maple and beech) over time, due to lack of regenerative capacity in undisturbed stands

- Occurs in almost pure, even-aged, fire-origin stands, mixed with hardwoods on upland sites and with hemlock around lakes

- Most productive on moist lower slopes (MR 3 to 5) with deep loamy soils and a moving (telluric) water table; more tolerant of poor drainage than sugar maple. Also found on sandy to fine loamy and occasionally organic soils (***see*** FIGURE 4.0.6)

FIGURE 4.0.6: Frequency and per cent cover of yellow birch >10 m tall from 1,539 FEC plots in Central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that had yellow birch. The right (black) bar indicates the mean per cent cover of yellow birch across all plots within a texture class



- Usually replaced by beech in association with sugar maple on dry to fresh sites.

4.3.2 Reproduction

- Species is monoecious, with unisexual flowers (catkins)

- Cone-like female catkins emerge with leaves in spring; late frosts may abort the seed crop

- Seed ripens in September or October, dispersal begins after leaf fall, with the onset of cold weather and continues through early winter (November to February); conelets slowly disintegrate during dispersal phase

- Wind dispersal of seed occurs over distances of up to one kilometre on snow crust; more commonly dispersal extends two to four tree-heights from the parent tree

- Seed with highest viability tends to fall earliest and in closest proximity to parent tree (tends to be heavier); low viability is often associated with a poor seed year

- Seed is occasionally sterile (“parthenocarpy”)

- Seed production begins at age 40 years (about 12 cm DBH), although fruiting has been observed on 9-year-old trees

- Most abundant seed production occurs after age 70 years (when trees are more than 20 cm DBH)

- Good seed crops occur every three years (allowing three crops in ten years); can be forecast by presence of male catkins on twigs in previous winter; bumper crops occur at ten-year intervals

- Can form sprouts from seedlings or small stumps, but such sprouts usually have low vigour; root suckers do not occur.

4.3.3 Establishment

- Seed exhibits embryo dormancy requiring cold stratification; seed germinates best at a higher temperature threshold (16° C) than sugar maple, slightly delaying establishment

- Germinative capacity is variable (30 to 60 per cent), usually higher in a good seed year; viable seed rarely lasts until second year

- Does not establish on undisturbed sugar maple litter because the small germinant radicle is not strong enough to penetrate matted maple litter

- May become established in hemlock litter or birch litter that shows curl-drying effect; often reproduces on rotting fallen stems or stumps, producing a stilt-rooted or “perched” birch

- Humus or moist mineral soil exposed by logging, fire or windthrow provides a good medium for germination; best survival and growth requires some organic material (humus mixed with mineral soil)

- Considered intermediate in shade tolerance (between black cherry and sugar maple)

- Establishment requires partial shade (40 per cent canopy is ideal); adequate moisture and moderate soil temperature are required for seedling survival

- Seedlings must attain heights of 15 cm in the first year to prevent smothering by subsequent maple and beech leaf fall

- Once established, seedlings need overhead light to grow adequately relative to tolerant competition

- Often successfully regenerates and competes in small openings of 0.1 ha or less; in larger openings, birch is often confined to edges or borders of a patch.

4.3.4 Development

- Height growth is indeterminate, beginning about mid-May and at times continuing until fall frost (early September); shoot tip of last of successional growth flushes usually aborts

- Given adequate light (e.g. basal area less than 9 m^2/ha), yellow birch will grow faster in height than either sugar maple or beech regeneration

- Response of height development is inversely proportional to overstory stocking level for the first 20 years; internode lengths of 75 cm per year may be expected at basal areas of 6 m^2/ha

- Diameter growth rate is moderately low; crown size is often smaller than sugar maple for trees of similar size

- Relatively *inelastic*; does not respond to release from severe suppression and responds only moderately to release from light suppression

- Self prunes well when adequate regeneration stocking is attained

- Develops a shallow, wide-spreading (plate-type) root system; trees are subject to wind throw on thin or saturated soils

- Decline symptoms, post-logging decadence and profuse epicormic branching often occur on residuals in excessively opened stands

- Initial requirement for partial shade and seedbed preparation followed by gradual release suggests shelterwood as a form of even-aged management, or group selection if managed with uneven-aged sugar maple.

4.3.5 Damaging Agents

- Yellow birch is one of the most defective of the valuable hardwoods in Ontario, particularly in trees greater than 100 years of age, averaging 42.3 per cent cull in Site Regions 4E and 5E

- Annual volume losses from decay in yellow birch were estimated to be 158,000 m^3 per year from 1982 to 1987 (***see*** TABLE 4.0.1)

- Brown stain accounts for 70 per cent of the defect; of the remaining defect, 15 per cent is caused by yellow-brown stringy rot, followed by white spongy rot and incipient yellow rot

- Forty per cent of decay infections are caused by *Stereum murraii* (Berk. & Curt.) Burt (yellow-brown stringy trunk rot), which together with *Pholiota adiposa* (yellow-brown stringy trunk and butt rot) and *Fomes igniarius* (white spongy trunk and butt rot) constitutes nearly 70 per cent of all yellow birch decay infections (Basham and Morawski 1964)

- Cull volumes increase consistently with tree size and were found to be higher in Algoma than in the Algonquin Ecological Section (Morawski *et al.* 1958), perhaps due to slower growth and greater ages in Algoma

- Cankers caused by cyclical infections of *Diaporthe* (*Phomopsis*) *alleghaniensis* Arnold periodically kill regeneration and small saplings. Target cankers caused by *Nectria galligena* occasionally girdle large saplings

- Birch leaf miner and birch leaf skeletonizer (*Bucculatrix canadensisella* Cham.) cause reductions in effective leaf area and subsequent reductions in growth; gypsy moth (Lymantria dispar L.) includes yellow birch as a food source

- Forest tent caterpillar (*Malacosoma disstria* Hubner) causes defoliation and is estimated to have reduced volume growth by 6,000 m^3 annually in the period 1982 to 1987 (***see*** TABLE 4.0.1)

- Trees weakened by stress may be attacked by bronze birch borer (*Agrilus amxois* Gory), often resulting in mortality

- Birch dieback, a disease of unknown origin, caused considerable growth reduction and tree mortality in the 1950s; deterioration of residual trees (post-logging decadence) is common in stands that have been excessively cut over

- Stem girdling from repetitive seasonal drilling by yellow-bellied sapsucker (*Sphyrapicus varius* L.) can cause top dying and mortality of trees of all sizes

- Bark and branch stripping by porcupines may cause severe reduction in growth, poor form development and death from resulting suppression

- Yellow birch is a favoured browse species of white-tailed deer and also is extensively clipped by hares in peak population years.

4.4 Red Oak

4.4.1 Habitat

- Occurs in areas with mean annual temperatures above 4° C; requires 1,333° C growing degree-days per year

- Occurs in areas with mean annual precipitation ranging from 500 to 1,500 mm, but grows best on sites that are fresh throughout the year

- Often occurs on dry sites, but these usually have a north or east aspect that is cooler than average for the area

- Usually a minor component of successional stands

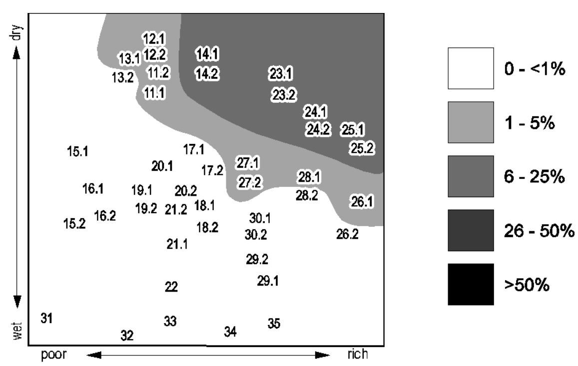
- Trees commonly grow to be 20 to 25 m tall and 30 to 90 cm DBH but may exceed 30 m and 120 cm, respectively, under ideal conditions

- Best growth occurs on fresh-to-moist, well-drained soils in coves and mid/lower slopes; toward its northern limit, red oak may form pure stands on rocky ridge crests

- In central Ontario red oak has its highest per cent cover on fresh to dry, rich to moderately fertile ecosites (***see*** FIGURE 4.0.7). Best sites are characterized by fresh, loamy soils (MR 2 to 4), but species may reproduce more easily and be found more frequently on drier, coarser-textured sites (MR 0 to 1) (see FIGURE 4.0.8).

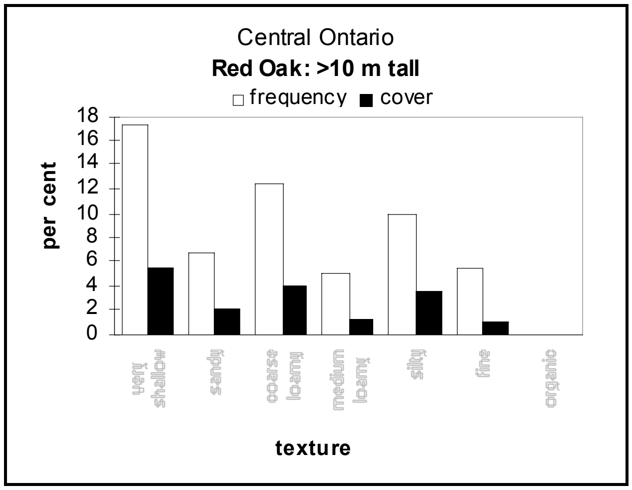
- Aspect and slope appear to be important factors affecting stem quality.

FIGURE 4.0.7: Mean per cent cover of red oak canopy trees by ecosite and in relation to soil moisture and fertility from 1,539 FEC plots in Central Ontario. Numbers indicate ecosite types. Refer to Section 3.4 “Ecosystem Classification” for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

FIGURE 4.0.8: Frequency and per cent cover of red oak >10 m tall from 1,539 FEC plots in Central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that had red oak. The right (black) bar indicates the mean per cent cover of red oak across all plots within a texture class



4.4.2 Reproduction

- Species is monoecious; male and female flowers develop with leaves in late April or early May

- Acorns require 18 months to mature; they ripen in September and October of the year following fertilization

- Acorns are dispersed by gravity in September through November falling near parent tree

- Squirrels or mice consume or transport and cache significant quantities of seed; caches may constitute important colonization opportunities for species

- Acorns are an important food for a large number of wildlife species

- Acorn production begins at 20 to 30 years of age; optimum yields are attained at 50 to 75 years (yields are poor after age 250 years)

- Acorn production increases with DBH up to 60 cm; crown size is important

- Dominant trees produce most seeds; south and west sides of crowns produce more acorns per unit area

- Seed production is related to stand density; site quality affects only acorn weight

- Individual trees show consistent seed production characteristics; good seed crops occur every two to ten years, with complete failures in some years

- Reproduces easily by stump sprouting; small stumps sprout more frequently than large stumps

- Stems of seedling-sprout origin are as good as seedlings and can develop into thriving trees

- Sprouts originating at root collar or below ground develop less decay because of an independent root system.

4.4.3 Establishment

- Seed exhibits dormancy requiring cold stratification; seeds remain viable for only one winter

- Ideal seedbed for acorns is moist, well-drained mineral soil; seed germination is best when buried two centimetres in soil with light litter cover

- Oak seedlings are more numerous where mineral soil has been disturbed (e.g. by fire or logging)

- Germination is followed by vigorous, rapid tap-root development

- Adequate regeneration occurs only in years of high seed production due to serious seed predation (by squirrels and birds) and insect damage (which results in wormy acorns)

- Shade tolerance is intermediate (less than sugar maple but more than black cherry)

- Survives only a few years under dense canopy; may survive several years under moderate canopy, but top usually dies and re-sprouts

- Once established, requires full light for survival and growth; makes more rapid height growth under such conditions than its more tolerant associates.

4.4.4 Development

- Height growth is determinate and is 90 per cent complete in 40 days

- Species asserts dominance at an early age by rapid expansion of crown

- Relative diameter growth is usually greater than that of common hardwood associates; trees often average one centimetre per year of diameter growth on good sites

- Productivity is greatly influenced and determined by soil moisture

- Responds well to release from moderate suppression; sapling and pole-sized dominants or codominants respond best

- Susceptible to epicormic branching following heavy release; dominant and codominants develop fewer sprouts than suppressed trees and there is less serious development in older trees

- Forest-grown trees show good self-pruning; trees often have straight trunks free of branches for 50 per cent of height

- Root system is deep and spreading and may include a tap root; may form root grafts with companion oaks

- Group selection or shelterwood systems are recommended, depending on stand composition and management objectives (group selection using small openings will require frequent tending).

4.4.5 Damaging Agents

- Although relatively decay-resistant, annual volume losses from decay have been estimated to be 11,000 m^3 per year from 1982 to 1987 (***see*** TABLE 4.0.1). Studies in the United States have estimated that cull averages 19 per cent in oaks (Baxter 1943)

- In American studies, the most important white trunk rot infecting red oak is *Polyporus compactus* Overh., which accounts for 36 per cent of infections and, together with *Stereum frustulatum* (Pers. ex Fr.) Fckl., *Stereum gausapatum* (Fr.) Fr. and *Inonotus* (*Poria*) *Andersonii* (Ell. & Ev.) Cerny, constitutes 80 per cent of all trunk rot infections. The major brown butt rot is *Laetiporus* (*Polyporus*) *sulphureus* (Bull. ex Fr.) Bond. & Sing., which accounts for 33 per cent of infections (Berry and Lombard 1978)

- A major insect problem is the oak leaf shredder; it has caused an estimated annual volume loss of 5,000 m^3 per year and mortality of 20,000 m^3 per year in (Gross 1985)

- A favoured food for forest tent caterpillar (*Malacosoma disstria* Hubner) and gypsy moth (*Lymantria dispar* L.), successive years of defoliation can lead to mortality. Infestations of oak skeletonizer can cause severe defoliation

- Oak decline complex is a stress-related dieback that is closely associated with the oak leaf shredder. Decline is also related to defoliation by forest tent caterpillar and gypsy moth. *Armillaria* complex (shoestring root rot) may be involved in aggravating the condition.

- Stem borers causing degrade of wood products are the carpenterworm (*Prionoxystus robiniae* Peck.) and red oak borer (*Enaphalodes rufulus* Haldeman). Galleries created by these pests may become infected with decay fungi

- Acorn weevils (*Conotrachelus* spp.) can cause serious losses in seed viability in epidemic years

- *Strumella coryneoides* Sacc. & Wint. causes a severe, girdling canker on oak, similar in appearance to that associated with *Eutypella* on maple. Canker and dieback of oak can also be caused by *Dothiorella quercina* (Cooke & Ell.) Sacc.

- A potentially lethal vascular disease known as oak wilt, common in the U.S. Lake States but as yet undetected in Canada, may threaten the oak resource in the future. It is spread by an insect vector, usually *Nutidulid* sap-feeding beetles

- Deterioration has been associated with weakening by glaze damage with subsequent infection by *Armillaria* spp..

4.5 White Ash

4.5.1 Habitat

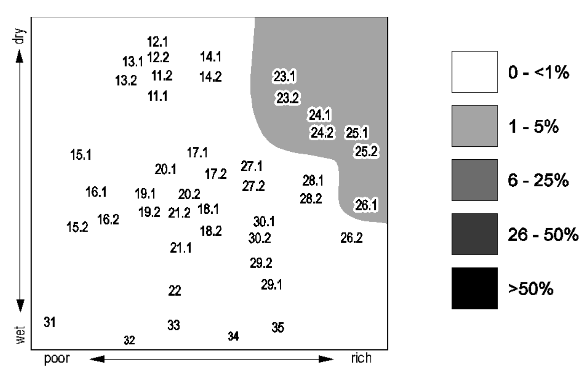
- Grows where the mean January temperature is greater than -12° C

- Restricted to areas with a growing season in excess of 180 days and 1,333° C growing degree days

- Requires 760 mm or more of annual precipitation

- A minor but frequent component of the eastern mesophytic forest; characteristic of early and intermediate stages of natural plant succession. In central Ontario, at the northern limit of its range, white ash is restricted to ecosites that are fresh to dry, but fertile (***see*** FIGURE 4.0.9)

FIGURE 4.0.9: Mean per cent cover of white ash canopy trees by ecosite and in relation to soil moisture and fertility from 1,539 FEC plots in Central Ontario. Numbers indicate ecosite types. Refer to Section 3.4 "Ecosystem Classification" for ecosite type descriptions

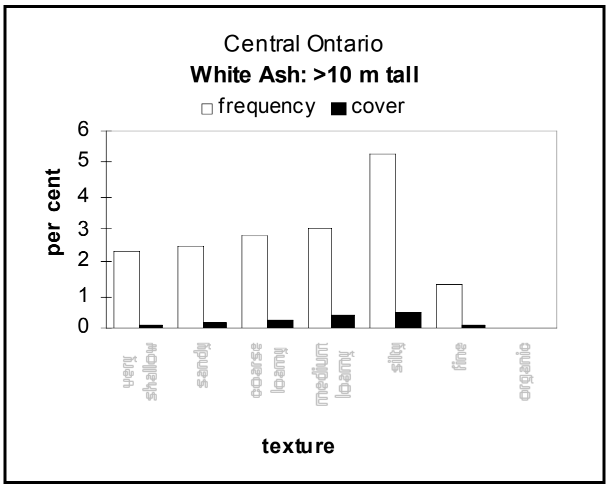


a) Central Ontario ecosites (1,539 FEC plots)

- Trees are commonly 20 to 25 m tall with diameters of 45 to 60 cm; occasionally trees may be 30 m tall and 90 cm DBH

- Demands substantial soil fertility and moisture; grows best on fresh-to-moist, well-drained sites (MR 2 to 4) with sufficient nitrogen and calcium (***see*** FIGURE 4.0.10)

FIGURE 4.0.10: Frequency and per cent cover of white ash >10 m tall from 1,539 FEC plots in Central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that contained white ash. The right (black) bar indicates the mean per cent cover of white ash across all plots within a texture class



- Common on luvisols and brunisols with pH greater than 5; grows well in soils underlain by compacted till supporting a telluric water table

- Considered a soil-improving species.

4.5.2 Reproduction

- Species is dioecious; male trees flower heavily most years while female trees flower only two to three years out of every five years

- Flowers bloom before leaf buds enlarge; pollination is confined to a very local area and requires 10 to 15 trees per hectare for seed production

- Fruit (samara) ripens in mid-August/October; seeds are wind-dispersed up to 150 m or two to three tree-heights in early winter

- Good seed crops are produced every three to five years

- Flowering may commence when trees are 8 to 10 cm DBH but more commonly begins at 20 to 25 cm DBH
- Minimum age of seed production is 20 years; maximum age is 175 years
- Spring flower crops are a good predictor of seed crops
- Seed production is inversely related to stand density
- Stumps of freshly cut or burned seedlings and saplings sprout readily and grow rapidly.

4.5.3 Establishment

- Seed exhibits embryo dormancy requiring two to three months of moist, cool stratification
- Field germination is relatively low; many seeds rot over winter
- Shows delayed germination, with up to 75 per cent germinating in the second spring; seed may remain viable for three years
- Minimum seedbed requirement is light litter; may seed-in readily on fertile abandoned fields
- Shade tolerance is intermediate; shade-enduring when young; can establish in 3 per cent full light, but best growth occurs in 45 per cent full light
- Often more commonly present in the understory than the overstory; may require 3 to 15 years to grow to breast height
- With increasing age, becomes more intolerant of shade
- Sprouts often grow faster than seedlings (40 cm per year).

4.5.4 Development

- Usually leafs out later than associated species, which can create small patches of warmer, higher light conditions on the forest floor under individuals or groups of ash trees in the early spring
- Shows determinate shoot-growth pattern; height growth is 90 per cent complete in the first 30 days and 100 per cent complete in 60 days
- Post-juvenile growth rates are relatively fast; may attain 10 cm DBH and 11 m in height by age 20 years and 30 cm DBH and 23 m in height at 50 years

- Dominant and codominant trees show good response to thinning or release; species shows good positive correlation between basal area growth and crown diameter

- Shows strong apical dominance and low susceptibility to epicormic branching

- Good self-pruner; branches fall two to five years after death; clear lengths in excess of 40 per cent of height are possible in trees 30 m tall

- Live-pruned branch scars heal very quickly

- May be successfully reproduced by a variety of management systems.

4.5.5 Damaging Agents

- Decay is not a severe problem and has not been investigated thoroughly in Ontario. In the United States, estimates of eight per cent cull have been noted by Baxter (1943)

- Annual volume losses in Ontario have been estimated to be 128,000 m^3 per year over the period from 1982 to 1987 (***see*** TABLE 4.0.1)

- White mottled rot (*Fomes fraxinophilus* [Pk.] Sacc.), white rot (*Polyporus gilvus* [Schw.] Fr.) and spongy white rot (*Polyporus hispidus* [Bull.] Fr.) are specific to ash

- Canker and branch mortality are caused by *Cytospora* (*Valsa*) *pruinosa* (Fr.) Hohnel.

- Leaf diseases causing crown thinning and defoliation are caused by ash leaf spot (*Marssonina martinii*), ash leaf rust (*Puccinia sparganioides* Ell. & Barth.) and anthracnose (*Aureobasidium apocryptum* (Ellis & Everh.) Herm.-Nijh.)

- Insects causing leaf destruction and defoliation include fall webworm (*Hyphantria cunea* (Drury)) and spiny ash sawfly (*Eupareophona parca* (Cresson))

- Boring insects that degrade xylem tissue and create infection courts for fungi include ash borer (*Podosesia syringae* Harris and carpenterworm (*Prionoxystus robinae* (Peck.))

- The ash flower gall mite (*Aceriafraxini flora* Felt) causes abortion of male flowers

- Ash dieback or decline occurs cyclically and is of unspecified origin. Chlorosis and dieback of ash has been associated with a mycoplasma (ash yellows), as well as with tobacco ring spot virus and tobacco mosaic virus. *Armillaria mellea* has also been associated with stress related ash dieback conditions.

4.6 Black Cherry

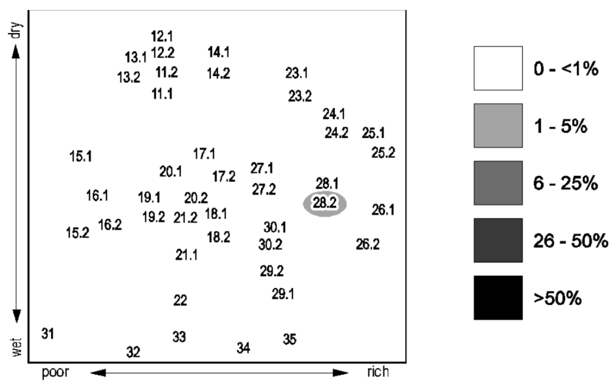
4.6.1 Habitat

- Requires cool, moist sites but seldom occurs north of the 5° C mean annual isotherm

- Species is neither resistant to high temperature nor extremely frost-hardy

- A minor component of the eastern mesophytic hardwood forest. It is found on a wide range of ecosites in central Ontario, but usually with a low per cent cover (***see*** FIGURE 4.0.11)

FIGURE 4.0.11: Mean per cent cover of black cherry canopy trees by ecosite and in relation to soil moisture and fertility from 1,539 FEC plots in central Ontario. Numbers indicate ecosite types. Refer to Section 3.4 "Ecosite Classification" for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

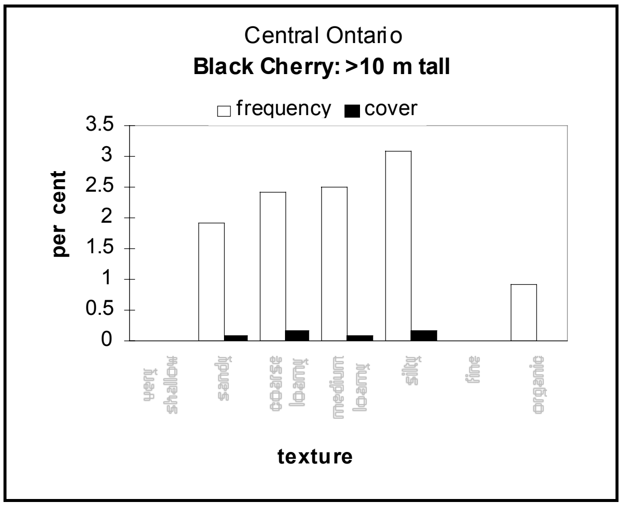
- Commonly 20 to 25 m tall with DBH of 45 to 60 cm; may reach 30 m in height in its southern range and may develop poor form (sweep) toward its northern limit

- Seldom exceeds 200 years of age

- Grows best on moist (MR 3 to 4), rich, well-drained loamy soils; lower slopes and coves are often suitable (FIGURE 4.0.12)

- Often occurs on north- and east-facing slopes; dry ridges provide unfavourable growing conditions.

FIGURE 4.0.12: Frequency and per cent cover of black cherry >10 m tall from 1,539 FEC plots in central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that contained black cherry. The right (black) bar indicates the mean per cent cover of black cherry across all plots within a texture class



4.6.2 Reproduction

- Species is monoecious, with perfect flowers that are pollinated by insects
- Flowers appear at the ends of new twigs after first leaves are fully developed (early June); flowers may be damaged by late spring frosts
- Fruit is a drupe, ripening in late August, with bulk of crop falling near parent tree before late autumn
- Songbirds may distribute seed by regurgitation or by droppings
- Good seed crops occur every three to four years; individuals produce some seed most years
- Viable seed is produced in open-grown trees as young as 10 years and in trees as old as 180 years; seed crops decline after 125 years
- Flower crops are not well related to seed crops
- Seed production is inversely related to stand density
- Individual trees tend to be consistent in seed production (i.e. always good or always bad)

- Sprouts readily from stumps of all sizes; those from merchantable-sized stumps generally develop poor form and rot.

4.6.3 Establishment

- Seed dormancy requires cool stratification for 120 days
- Seeds may remain viable for three years or more in soil
- Seedbed requirements are not rigid; undisturbed leaf litter or exposed mineral soil is satisfactory; compacted soil is a poor substrate
- Seed buried to a depth of 15 cm in soil may germinate and survive
- Species is intolerant of shade; seedlings will not survive or grow substantially under closed canopy; requires free or dominant crown to survive
- May grow 5 to 10 cm within first 30 days of germination; in open conditions, height growth of 45 cm is possible
- Seedlings develop a tap root when young, which is not seen in saplings.

4.6.4 Development

- Height growth is determinate and is 90 per cent complete within eight weeks
- Species has a medium growth rate (greater than beech and less than red oak)
- Diameter growth is rapid up to age 50 years in pure stands and may average 10 cm per decade from 10 to 30 years of age
- In occasional pure, even-aged stands, young trees readily express dominance and differentiate into various crown and diameter classes
- Generally shows poor response to release; subdominants lack capacity to recover from partial suppression; vigorous trees may show some response to thinning
- Root system is shallow; trees are subject to windthrow, especially on poorly drained sites
- Sudden exposure may produce sunscald, stag-head and general decadence; species is prone to produce epicormic branches
- Will develop satisfactorily in even-aged patches or strips equal in width to the height of border trees.

4.6.5 Damaging Agents

- Annual volume losses due to decay average 1,000 m^3 per year from 1982 to 1987 (***see*** TABLE 4.0.1)

- Common causes of brown cubical rot are *Polyporus sulphureus*, *Fomes pinicola* (Schwartz) Cke. (trunk rot) and *Coniophora cerebella* Pers. (butt rot). *Polyporus berkeleyi* Fr. is a common white butt rot

- Branch mortality and crown-thinning are caused by black knot (*Apiosporina morbosa* (Schwein.:Fr.) v. Arx) and *Cytospora* canker *Nectria galligena* is associated with target canker of stems

- Defoliation by eastern tent caterpillar (*Malacosoma americanum* (Fabricius)) and ugly nest caterpillar (*Archips cerasivoranus* Fitch) periodically causes loss of vigour and reduced growth

- Gum spot, a serious lumber defect, is associated with attacks by the peach bark beetle (*Phloeotribus liminaris* Harris)

- Pith fleck is caused by the cambial mining of *Dipterous* larvae of *Agromyza pruni* and *Phytobia pruinosa*

- Stems are attacked by peach tree borer (*Sanninoidea exitiesa*), which forms galleries and may provide infection courts for fungi

- Susceptible to glaze damage and vulnerable to fire.

4.7 Basswood

4.7.1 Habitat

- Northern limit lies close to 18^o C mean July isotherm throughout its range; requires a minimum of 200 mm of growing-season precipitation

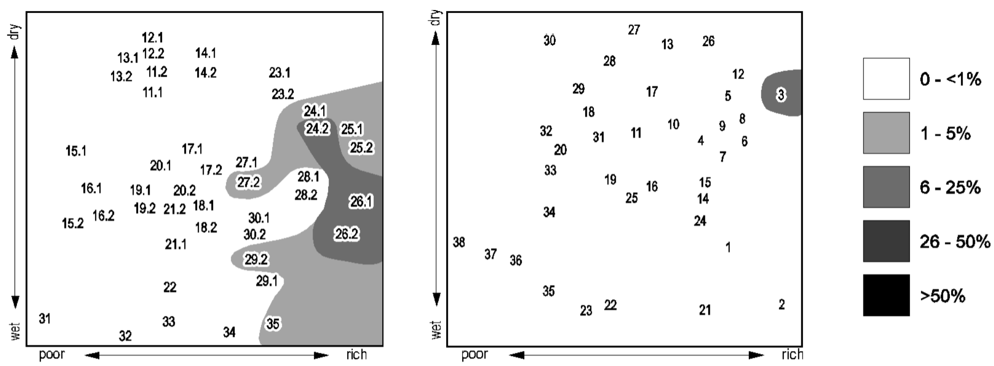
- Maximum development occurs in areas averaging 18^o C to 27^o C in July and receiving 250 to 380 mm of precipitation during the growing season

- May be rare or absent at higher, cooler elevations (i.e. on Algonquin Dome with < 85 frost-free days)

- Dominant member of the eastern mesophytic climax only in the Sugar Maple-Basswood cover type (SAF #26), of the dry/humid central plains of the U.S.; occurs as an outlier in isolated groups in Site Region 5S, in the Quetico and Rainy River Sections of the Great

Lake-St. Lawrence Forest Region (where it is restricted to Vegetation Type 3, similar to yellow birch and sugar maple (FIGURE 4.0.13b). In central Ontario, it is restricted to fresh-to-wet, moderately rich to rich ecosites. It reaches its highest per cent cover on fresh, rich sites (FIGURE 4.0.13a)

FIGURE 4.0.13: Mean per cent cover of basswood canopy trees by ecosite and in relation to soil moisture and fertility from FEC plots sampled in Ontario. Numbers indicate ecosite types. Refer to Section 4.3 "Ecosite Classification" for ecosite type descriptions



a) Central Ontario ecosites (1,539 FEC plots)

b) Northwestern Ontario vegetation types (2,139 FEC plots)

- Considered to be a key species of the Sugar Maple-White Ash-Basswood and Lowland Mixed Hardwoods cover types of Site Regions 6E and 7E in southern Ontario

- Does not occur as pure stands; usually found in mixture with sugar maple, beech, white ash, hickory and red oak in the Deciduous Forest Region and with sugar maple, yellow birch, hemlock and white pine in the Great Lakes-St. Lawrence Forest Region

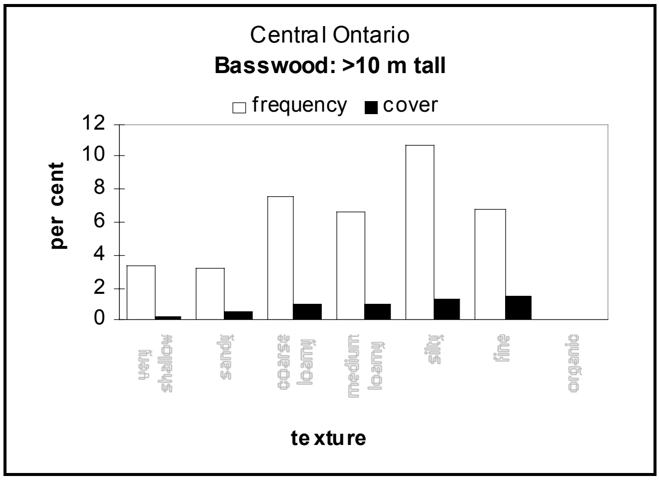
- Frequently occurs as even-aged coppice in stands after major disturbance; may occur irregularly as a secondary component in uneven-aged stands

- Occurs commonly (but irregularly) on deep/moderately-deep, fresh (MR 2 to 3) sandy loams and telluric moist (MR 4 to 6) cool sites in Site Region 5E; also found on fresh loamy soils in Site Regions 6E and 7E and fresh clay soils in Site Region 6E (***see*** FIGURE 4.0.14)

- Requirements for moisture are moderate and very high for nutrients (a nitrogen demanding species)

- Stems commonly 60 to 90 cm DBH and 20 to 30 m in height (rarely 120 cm and 35 m respectively); moderately long-lived (100 to 150 years, rarely 200 years).

FIGURE 4.0.14: Frequency and per cent cover of basswood >10 m tall from 1,539 FEC plots in central Ontario by soil texture class. The left (white) bar indicates the percentage of plots within a texture class that had basswood. The right (black) bar indicates the mean per cent cover of basswood across all plots within a texture class



4.7.2 Reproduction

- Species is polygamous with perfect (bisexual) flowers pollinated by insects. Flowers appear in June or July, about 6 to 8 weeks after leaves expand

- Seed pods form pendulous clusters (cymes) with an attached leaf-like bract. Fruits are woody, non splitting drupes and remain on the tree into the winter

- Commercial seed-bearing age is 10 to 100 years (fruiting has been noted at age 10 years)

- Abundant seed crops are produced almost every year (62 per cent of the time). Repeated successive good seed years are common, rare for fall-maturing species

- Fruit ripens in October; seed is dispersed from November through the winter

- Seeds are dispersed by gravity, animals and wind. Seed dispersed by wind limited to 150 m (two tree-lengths from parent tree)

- Basswood is a prolific stump sprouter; sprouting ability may remain until age 100 years

- Nearly all trees up to 25 cm DBH and nearly half of all sawlog stems, may sprout when cut

- Reproduction of basswood may be entirely vegetative in many areas.

4.7.3 Establishment

- Basswood seed exhibits delayed germination (8 months to 7 years) after dispersal because of an impermeable seed coat, dormant embryo and tough pericarp

- In mixed hardwood stands, the seed bank may show basswood as a dominant component

- Delay in germination allows much of the seed stored on forest floor to be destroyed; seeds covered by litter tend to rot, while seeds lying on surface of the ground are often destroyed by rodents, by insects and fungi (only 5 per cent sound after 2 years)

- Despite heavy, frequent seed crops, less than five per cent of basswood seed bank may be viable

- Seed collected early (September) has higher moisture content and viability; seed will germinate at 2^{o} C

- High germination (90 per cent) of fresh seed can be obtained by acid scarification, hormone treatment and cold storage (4^{o} C)

- A well-decomposed humus seedbed avoids pests, promotes germination and provides nutrients to developing seedlings

- Root system is a long tap root initially, later developing lateral roots from an oblique central mass

- Seedlings are intermediate in shade tolerance; shade tolerance increases with age and mature trees are very tolerant

- Shading (25 per cent light) aids establishment and early survival but limits subsequent growth and development. Seedlings cannot sustain themselves under a partial canopy

- Use shelterwood system for seed-based regeneration to provide shade and suitable microsite for germination. A heavy seed crop occurring 2 years before cutting is required. Overstory should be removed after establishment (in three years). Stocking results are very unpredictable

- Group selection can be used to release seedling sprouts or advance growth

- Shoot growth is indeterminate or sustained, characterized by final shoot-tip abortion. Height growth period is 9 weeks

- Seedling sprouts (parent DBH < 5 cm) formed as a result of logging damage, will usually grow faster than seedlings of same age

- Stump sprout clumps often contain 10 to 16 sprouts. Sprout mortality may be 30 per cent over 16 years from initiation

- Sprout mortality usually shows an exponential dropout rate and decreases with increasing parent stump diameter.

4.7.4 Development

- Basswood has one of the highest potential growth rates among its hardwood associates

- Forest-grown trees have compact, narrow crowns that allows a higher stocking level to be carried than for most of its hardwood associates

- Trees self-prune well, develop long, clean boles but are susceptible to epicormic branching

- Radial growth may continue for up to 15 weeks. Annual DBH growth can be 3 mm per year in unmanaged stands and group selection cuttings, 4.6 mm per year in crop-tree release and 4.8 mm per year in single-tree selection cuts

- Sprouting allows basswood to maintain itself in a maple stand. Extensive root systems give sprouts a higher probability of replacing parent stem's growing space than sugar maple seedlings, despite larger numbers of sugar maple seedlings

- Sprout growth is rapid, allowing it to persist under the selection system (mainly on better sites). Sprouts originating at the root collar are acceptable growing stock

- Early sprout clump thinning, leaving no more than two residual sprouts, is essential; usually required in ten years or at DBH of 5 cm (maximum 7 cm).

4.7.5 Damaging Agents

- Average annual volume losses in Ontario have been estimated to be 2,000 m^3 over the period 1982 to 1987 (**see** TABLE 4.0.1)

- Major sources of decay are yellow-brown stringy rots caused by *Pholiota aurivella* (Fr.) Kum, *Pholiota spectabilis* (Fr.) Kum and *Armillaria ostoyae* (Romagn.) Herink.

- One of the least-decayed deciduous species in Ontario; rot volume is less than 5 per cent in trees younger than 120 years. Cull develops rapidly with subsequent age, up to 32 per cent at 180 years

- Older sprout stems may be hollow in lower portions ("stove pipes") due to rot entering from parent stump. Rot volume may be three times in sprout stems than in similar-sized seed-origin stems

- Basswood looper (*Erannis tiliaria* (Harris)), spring and fall cankerworms (*Paleacrita vernata* (Peck) and *Alsophila Pometaria* (Harris)) and gypsy moth (*Lymantria dispar* L.) cause periodic defoliation. Basswood thrips (*Sericothrips tiliae* Hood) feed on early-emergent leaves

- Seeds are eaten by mice, squirrels and chipmunks. Some seed is destroyed by a basswood seed feeder insect (*Phalonia straminoides* Grt.)

- Thin-barked trees are easily damaged by fire and are often girdled by meadow voles

4.8 Critical Silvics of Other Commonly Associated Hardwood Species

Managers must regularly consider a range of additional species not addressed at length in this guide. Forest managers should be aware of these features when planning their silvicultural strategies, since forest level objectives may dictate the need to encourage additional representation of such species, or to discourage them as competitors of higher priority species. A brief summation of critical ecological and biological traits is provided in TABLE 4.8.1 and TABLE 4.8.2 (*adapted from*: Anderson *et al*. (*in press*)).

TABLE 4.8.1: Ecological traits of associated hardwood species

SPECIES	SOIL REQUIREMENTS		SEEDBED	SHADE	CANOPY		RELEASE RESPONSE	BROWSE TOLERANCE
	MOISTURE	NUTRIENT			GAP SIZE	DENSITY		
Aspen, Trembling	medium	medium	moist mineral	very tolerant	> 1 ha	open	low	low
Birch, White	medium	medium	humus mix	intolerant	0.5 ha	20%	low	low
Maple, red	low	medium	litter	tolerant	0.08 ha	50%	very high	medium
Maple, silver	high	very high	litter	intermediate	0.1 ha	20%	high	medium
Ash, black	high	high	litter	intolerant	0.5 ha	20%	moderate to low	low
Oak, pin	low	low	litter	intolerant	0.3 ha	NO DATA	NO DATA	medium
Oak, white	medium	very high	litter	intermediate	0.2 ha	60%	NO DATA	medium
Oak, swamp white	NO DATA	NO DATA	litter	intermediate	0.2 ha	NO DATA	NO DATA	low
Elm, white	high	very high	moist mix	intermediate	0.1 ha	NO DATA	NO DATA	moderate to high
Hickory, shagbark	NO DATA	NO DATA	litter	intermediate	0.2 ha	NO DATA	high	high
Hickory, bitternut	medium	very high	litter	intolerant	0.4 ha	NO DATA	NO DATA	moderate to high
Walnut, black	low	very high	litter	intolerant	0.4 ha	NO DATA	medium	high
Butternut	NO DATA	NO DATA	litter	intolerant	0.4 ha	NO DATA	NO DATA	high
Tuliptree	NO DATA	NO DATA	humus mix	intolerant	0.4 ha	NO DATA	NO DATA	NO DATA

TABLE 4.8.2: Biological traits of associated hardwood species

SPECIES	SEED CROP	SEED DISPERSAL			SEED		SHOOT GROWTH		SPROUTING ABILITY*
		DATE	METHOD	DISTANCE	LONGEVITY	WEIGHT	TYPE	DURATION	
Aspen, Trembling	4-5 years	May/June	wind	1,000 m +	2-4 years	very light	sustained	90 + days	suckers++
Birch, White	2 years	Sept/Nov	wind	400 m +	2 years	light	sustained	90 + days	coppice
Maple, red	1-2 years	June/July	wind	100 m +	1-2 years	medium	recurrent	30 + days	coppice++
Maple, silver	1 year	May/June	wind	200 m +	1 year	med-heavy	NO DATA	30 + days	coppice++
Ash, black	1-8 years	Oct +	wind	150 m +	2-8 years	medium	preformed	NO DATA	coppice
Oak, pin	3-4 years	Sept +	grav/animals	local +	1 year	med-heavy	NO DATA	NO DATA	coppice+
Oak, white	4-10 years	Sept/Oct	grav/animals	local +	< 1 year	med-heavy	recurrent	NO DATA	coppice++
Oak, swamp white	3-5 years	Sept/Oct	grav/animals	local +	1 year	med-heavy	NO DATA	NO DATA	coppice
Elm, white	1 year	May/June	wind	400 m +	1 year	med-light	sustained	NO DATA	coppice
Hickory, shagbark	1-3 years	Sept/Dec	grav/animals	local +	1 year	heavy	preformed	NO DATA	coppice++
Hickory, bitternut	3-5 years	Sept/Dec	grav/animals	local +	1-2 years	heavy	preformed	NO DATA	coppice++
Walnut, black	2-5 years	Oct/Nov	grav/animals	local +	2-4 years	very heavy	preformed	80 days Ò	coppice –
Butternut	2-3 years	Sept/Oct	grav/animals	local +	4-7 years	very heavy	preformed	NO DATA	coppice –
Tuliptree	1 year	Oct +	wind	150 m +	1 year	medium	sustained	90 + days	coppice++

* Sprouting ability varies from very strong (++) to very weak (− −).

5.0 QUALITY DEVELOPMENT IN TREES

5.0 Quality Development in Trees

by Harvey Anderson and Dave Deugo

The comparatively high values (***see*** Section 2.2 "Commercial Importance") that are characteristic of products derived from the seven principal species of the tolerant hardwood forest are realized only when the material is of high quality. Any silvicultural undertaking, therefore, must not only recognize quality in standing forest trees, but also understand how these characteristics can be maintained or improved over time. The recognition and evaluation of both current and potential tree vigour, risk and quality are crucial elements in successfully applying both uneven-aged systems (which involve marking for individual tree selection) and even-aged systems (which require crop-tree identification and release). In addition, the maintenance of stand productivity objectives for yield and growth rate must be rationalized with these quality requirements and other factors such as site quality to provide maximum volume and value output per hectare.

For detailed information about appraising individual tree vigour, risk and quality, refer to: *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

5.1 Assessing Individual Tree Vigour Potential

Vigour potential may be defined as the relative capacity of a tree to increase in size (mainly in diameter and volume). Management of tolerant hardwood forest species is based on the premise that trees retained as growing stock have value-growth potential, which implies a vigour status allowing residual trees to develop quality-specific dimensions in a reasonable period of time.

Numerous vigour indices have been developed for many tolerant hardwood forest species for various purposes. Of particular interest are those developed for tolerant hardwoods (OMNR 1983; Mize and Lea 1977; Smalley 1975; Holcomb and Bickford 1952; Gevorkiantz 1956), for mixed hardwoods (DeBald and Mendel 1976; Minckler and Gingrich 1970; Trimble 1969) and for oak (Trimble 1960; Weitzman and Trimble 1957; Burkle and Guttenberg 1952).

Common to most vigour classifications are the following features that should be considered when choosing residual stems (Hamilton 1969; Smith 1954a):

- **Crown position**: Classifying trees by the position of their crowns in relation to the forest canopy (i.e. dominant, co-dominant, intermediate and overtopped or suppressed) provides an indication of the amount of direct sunlight received, which in turn regulates the tree's photosynthetic rate.

- **Crown size**: The size of the crown (length, width and volume) is an index of the leaf surface area available to trap light energy for photosynthesis and thus is an indicator of the amount of carbohydrate manufactured which in turn regulates growth. Crown dimension and space requirements for adequate growth vary with species and are outlined by Arbogast

- (1957), Smalley (1975) and Marquis *et al.* (1984) for crown diameter and by Lorimer (1983), OMNR (1983), Gevorkiantz (1956) and Ward (1964) for live crown ratio (LCR).

- **Crown quality**: Regardless of size and position, the crown must be healthy to perform its function well. Chlorotic or undersized leaves, dead twigs, coarse branches (relative to the species norm), low leaf density and flat-topped shape indicate low vigour (OMNR 1983).

- **Bark character**: For some species (notably hard maple, yellow birch and red oak), tree vigour can be determined by examining the firmness of the bark and the nature of its' fissures and ridges. Examples of this technique are outlined in OMNR (1983), Arbogast (1957), Burkle and Guttenberg (1952), Sajdak (1967), Clausen and Godman (1969) and Anderson and Rice (1993).

- **Degree of competition**: The stocking density of nearby, 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 listed above and the silvical characteristics of the species.

- **Stand relationships**: Consideration of individual tree vigour must be kept within the perspective of the overall management objectives for stand density, structure and species composition, as outlined in Section 6.0 "Stand Stocking and Structure".

5.2 Assessing Individual Tree Risk Potential

To have value potential, residual trees must survive and grow at least until the next cutting cycle (5 to 25 years). High risk trees are those that may either die or deteriorate significantly in quality due to rot development etc., during that period. These high risk trees are usually removed from the forest in early harvesting operations or improvement cuttings. However, in previously unmanaged stands, the average quality is such that some modest-quality trees may have to be retained for the purpose of stand stocking maintenance. Conversely, because of crown damage or excessive lean, high-value, vigorous trees may be considered high risk trees and therefore have low value potential.

Risk features are accounted for in the hardwood tree classification (***see*** Section 5.3 "Assessing Individual Tree Quality Potential") as "decline-causing defects". It is important, however, to discriminate between random decline events affecting occasional individual trees and multi-species, broad scale declines of undetermined origin.

5.3 Assessing Individual Tree Quality Potential

There is a fundamentally different philosophy involved in grading hardwood and softwood trees and their products. For hardwoods, species and grade are more important than volume in determining the value of lumber. Quality hardwood lumber is used for furniture and cabinetry 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, but for softwoods, it is the number and type of defects within a board and how they affect strength.

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

- **Tree DBH**: Value per tree increases with increasing DBH because of a correspondingly larger "quality-zone" component within the log(s), which yields a greater percentage of high-value lumber grades i.e. "selects and better" (Ostrander 1965; Petro 1962).

- **Site Region**: In one study, the percentage of "selects and better" lumber grades sawn from grade 1 logs was found to be 30.4 per cent in Site Region 5E compared to 49.3 per cent in Site Region 6E (Morawski 1971). This is a reflection of generally better growing conditions in Site Region 6E.

- **Cull Factor**: The overall extent of defect varies with site region, landtype and species. In Site Region 5E, cull percentage is lower in Algonquin (5E south) than in Algoma (5E north) for hard maple (30 per cent *vs*.36 per cent) and yellow birch (34 per cent *vs*. 42 per cent) for trees with a DBH of 46 cm. There is approximately 5 per cent less cull in hard maple growing on the Limerick landtype than on the Sherbourne landtype in Site Region 5E (Morawski *et al.* 1958), perhaps a reflection of the higher soil base content on the Limerick landtype.

- **Tree Growth Rate**: Potential quality is limited by the type of defect that occurs in a tree. However, the future growth rate of a tree can greatly influence the rate of value development, because the quality of defective trees may improve if their growth rate is sufficiently accelerated.

Estimates of cull (or quality) in hardwoods can be further refined by using tree classifications that recognize defect indicators and log quality and volume in the standing tree. A conceptual outline of a system used in the former Algonquin Region is shown in TABLE 5.0.1.

Descriptions of the features used in this classification have been published by numerous authors: Anderson and Rice (1993); Shigo (1984a, 1984b, 1983, 1965); OMNR (1983, 1973); Rast (1982); Basham and Anderson (1977); Carvell *et al.* (1973); Stayton *et al.* (1971, 1970); Marden and Stayton (1970); Stayton and Marden (1970); Shigo and Larson (1969); Lavallee (1968); Lavallee and Lortie (1968); Lockard *et al.* (1963); Hesterberg (1957b); Silverborg (1954); Zillgitt and Gevorkiantz (1948); and Hepting *et al.* (1940). Guidelines for quality-product grade specifications for hardwood growing stock have been presented by Boyce and Carpenter (1968), Sonderman (1979) and Sonderman and Brisbin (1978). Additional information on fungal, insect and abiotic effects is outlined in Section 4.0 "Silvics".

Harvesting and the estimation of volume and value involved, is an important element of silviculture. However, a silvicultural tree classification system must not only assess current quality in terms of product and value, but also evaluate the potential of a tree to respond to treatment and to increase, decrease, or maintain its quality until the end of the next cutting cycle. Such information is essential in determining the appropriate silvicultural system (using quality cruise data), formulating marking prescriptions, estimating harvest volume and value and estimating the potential growth and yield of the residual standing crop. It also facilitates the marking process by discriminating among similar crowded trees (i.e. indicating the trees with the greatest potential).

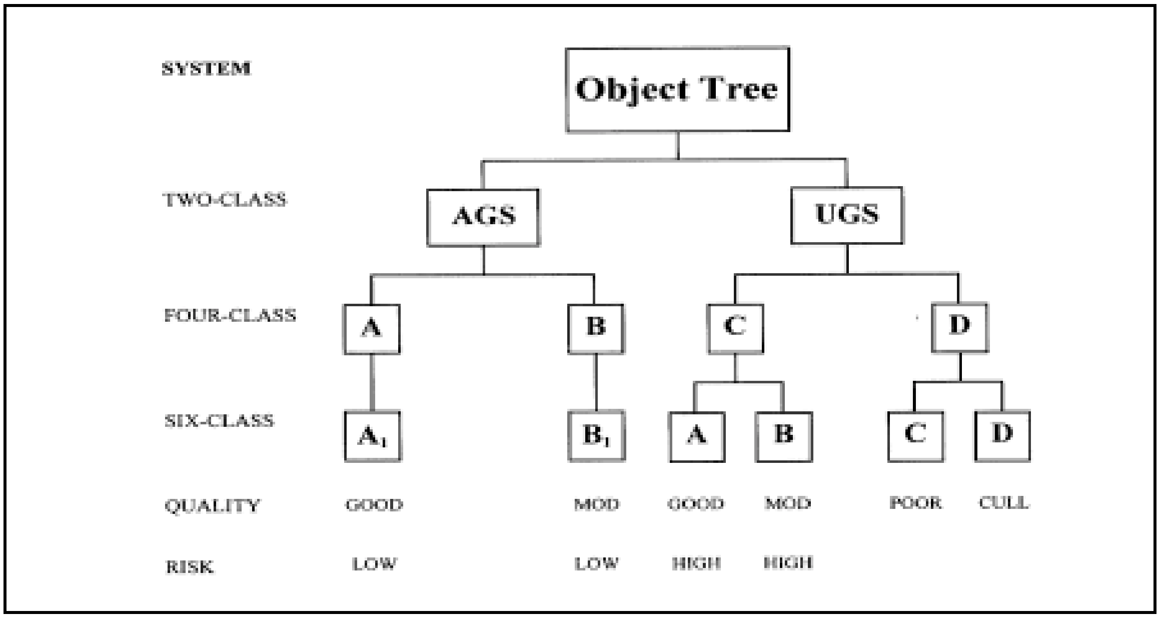
In the Algonquin classification (***see*** TABLE 5.0.1), trees are graded for potential value based on current quality or risk of decline (i.e. trees are classified as “A” for present high quality but low potential and “A1” for high potential quality). Other classifications may simply classify the trees as “acceptable growing stock” (AGS) or “unacceptable growing stock” (UGS). The Algonquin system can be simplified during compilation (A1 and B1, for example, become “AGS”), if desired. To allow comparison with historical data and to bridge between the most common current systems, the six-class system can be collapsed into four classes and ultimately into two classes, as shown in FIGURE 5.0.1. A more complete discussion of the nature and use of tree classification methods is given by Anderson and Rice (1993).

Lumber recovery studies carried out in Algonquin Park (McLean 1970; Anderson and McLean 1970) suggest that, if conversion costs are ignored and tree grade, merchantable length and lumber prices are assumed to be constant over time, nominal interest earned by trees growing at a rate of five cm in DBH over ten years decreases with increasing initial diameter. While there is a large differential in the increase in recoverable value of 66 cm trees ($13 in 1968) compared to 25 cm trees ($3 in 1968), the interest rate earned by high quality trees of these sizes is inversely related to tree size and varies with potential growth rate (***see*** FIGURE 5.0.2).

From a silvicultural perspective, therefore, medium-sized sawlog trees of good vigour and quality earn value at a higher rate and occupy less space in the stand than larger trees and are a better economic investment. Strategically, the manager attempts to transfer the growing space occupied by larger, mature trees to the high-potential, smaller, sawlog-size trees, by means of marking and harvesting. DeBald and Mendel (1976) have suggested methods to develop financially sound silvicultural approaches to hardwood management.

TABLE 5.0.1: Algonquin region tolerant hardwood tree classification (conceptual) (*from:*OMNR [1990])	
TREE CLASS	CLASS DESCRIPTION
A1	Trees that contain or are potentially capable of producing high-quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop-tree producers of high-quality sawlogs or veneer logs.
A	Trees that have bole quality equal to Class A1 trees, but that are of high risk or are expected to decline within a 20-year period. Such trees are normally best harvested immediately.
B1	Trees that contain or are potentially capable of producing medium quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop-tree producers of sawlogs for dimension lumber.
B	Trees that have bole quality equal to Class B1 trees, but that are of high risk or are expected to decline within a 20-year period. Such trees are normally best harvested immediately.
C	Trees containing or having the potential to produce low-quality logs but no better. Such trees are often used for pulpwood, poker poles, bolter logs, or fuelwood but are not normally considered as crop trees.
D	Cull trees as defined in the Scaling Manual: no sawlog potential, but that may be used for pulpwood or fuelwood if a strong market exists. **Note**: Merchantable hardwood trees contain one or more merchantable logs to a 20 cm top having a total content of sound wood that is equal to more than one third of the content of all the logs in the trees.
DEFECTS	
Value-affecting defects are mechanical or form defects. These defects limit or reduce the value of products that can be recovered from a tree but will not cause continued deterioration or decline. The size and position of these defects determines the degree to which they affect value. (Examples: wounds, cracks, seams, holes, dead limbs, branch stubs, live branches, twisted grain, bumpy surface, sweep, crook, forks, burls and lean.) **Decline-causing defects** are severe mechanical or pathological defects. These defects cause continued deterioration of the products that may be recovered from a tree. They may also severely limit the potential of a tree to produce anything better than low-value products (e.g. pulpwood, poker poles, bolter logs and fuelwood). (Examples: rot or decay when associated with value-affecting defects or when indicated by the presence of conks, fruiting bodies, cankers, barrelling, etc. Severe mechanical defects such as broken tops, excessive lean, or severe sugar maple borer damage will cause decline or cause the tree to be considered high risk.	

FIGURE 5.0.1: Relationships among two-, four- and six-class tree quality classification systems (*from*: Anderson and Rice 1993)



In even-aged stands, the relevant question for management involves the length of the rotation. In uneven-aged selection forests, the important question is related to how long an individual tree should be allowed to grow. Once an ideal stand structure is approached in a selection forest, the concept of financial maturity can become a factor in tree marking. One aspect of this process is to determine maximum diameters appropriate for individual trees of various qualities, merchantable lengths and potential growth rates (***see*** TABLE 5.0.2). These mature diameters can be selected on the basis of economic rate of return (allowing for conversion costs).

In consideration of these results, a general guideline for initial conditioning cuttings in the tolerant hardwood forest would be to use a maximum diameter of 60 cm in determining maturity. However, other considerations—for example, modifications for wildlife habitat improvement, or aesthetics—might change this structural limit. In some cases, trees larger than the economic optimum may be justifiably retained for some species. Conversely, in the northern transitional forest, growth rates and quality may be such that a maximum DBH, less than those suggested by TABLE 5.0.2 may be justified.

FIGURE 5.0.2: Relationship between interest rate earned and lumber value increase (1968 $) for crop-quality hard maple growing five cm in DBH in ten years (*from*: Anderson and McLean [1970])

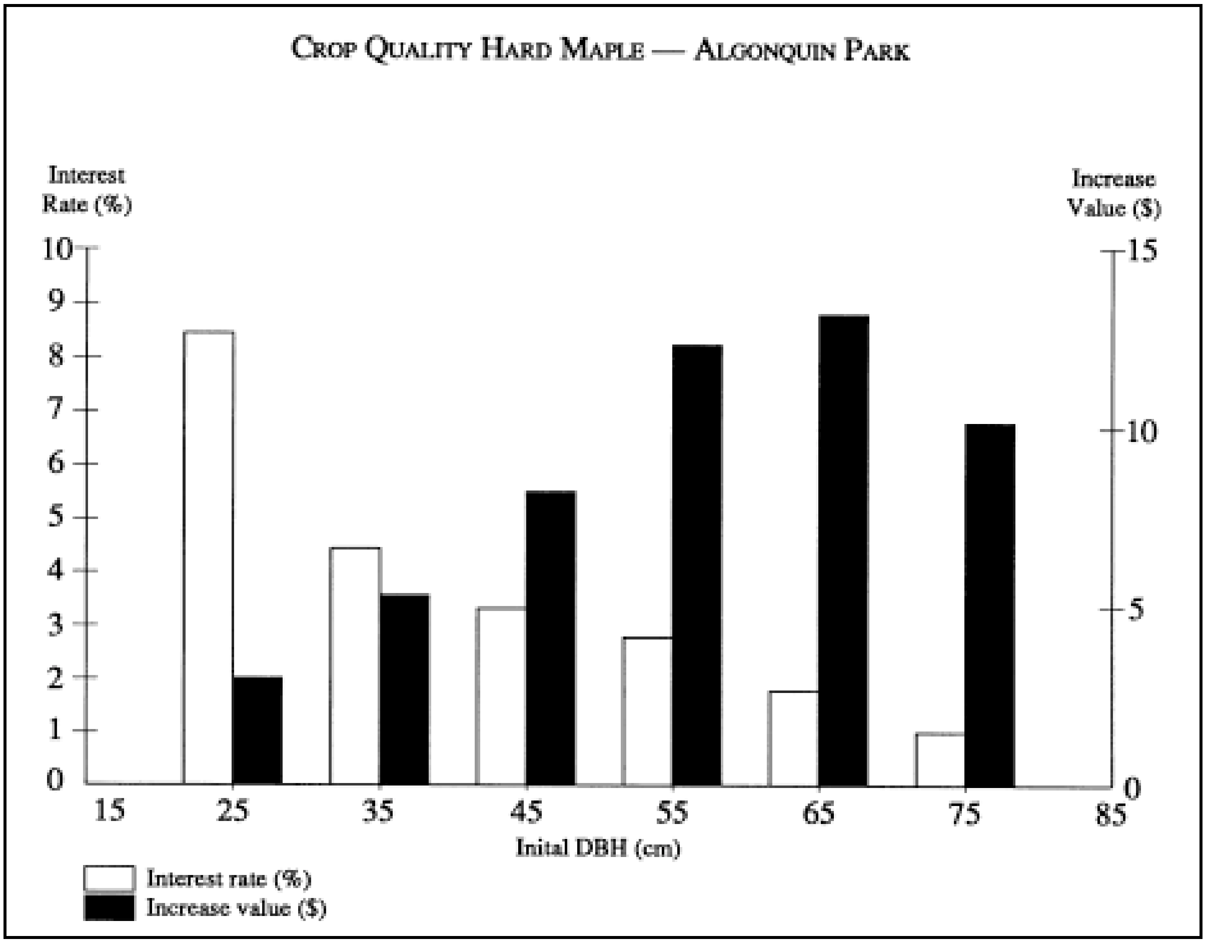


TABLE 5.0.2: Financially mature diameters for hardwood species of butt-log grade 1 and 2, based on growth rate alone over ten years (*from*: Mendel *et al.* [1973]; Grisez and Mendel [1972]; Mendel and Trimble [1969]; Trimble and Mendel [1969])

SPECIES	VIGOUR CLASS	RATE OF RETURN		
		2%	4%	6%
		MATURE DBH (cm)		
Mh	1	69	51	43
	2	61	46	38
	3	56	41	36
Aw	1	76+	56	41
	2	69	46	36
	3	58	36	
Cb	1	76+	56	41
	2	76	43	33
	3	69		
Be	1	58	48	43
	2	51	43	41
	3	48	41	
Or	1(SI 24)	71	56	51
	1(SI 18)	61	51	46
	2(SI 24)	64	53	46
	2(SI 18)	58	48	41

6.0 STAND STOCKING AND STRUCTURE

6.0 Stand Stocking and Structure

by James Rice, Murray Woods and Harvey Anderson

Optimization of growth and development in tolerant hardwoods occurs only when the stands are regulated in terms of stocking density and its relationship to size-class distribution and cutting cycle for uneven-aged stands and to age for even-aged stands. Consideration of species, site and management objectives will modify management procedures on a local scale. This section will outline the basic models that should be used as reference points in setting stand management goals for uneven-aged and even-aged systems. A comparison of stand attributes of even- and uneven-aged systems is given in TABLE 6.0.1. A more comprehensive discussion of this topic is contained in *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

6.1 Stand Stocking

By definition, stand *density* is expressed numerically on a per-unit-area basis, while *stocking is* a relative term, considered in relation to the stand desired for best growth (Bickford *et al.*1957). *Stocking level* is used here synonymously with *density level* to reflect the common use of the term used in uneven-aged silviculture.

Stocking levels for tolerant hardwoods are normally expressed in terms of basal area per unit land area (Zillgitt 1949), because such values are readily obtainable from point sample estimates. Stocking is less commonly expressed in terms of volume per unit area and can be estimated from basal area or developed by applying appropriate regional cull figures to gross merchantable volume (GMV) estimated from cruise data (species, DBH, merchantable length, tree quality) and standard volume tables (e.g. Form Class 79). For unmanaged even-aged stands, general estimates can be derived from site class yield tables (Plonski 1981; Love *et al.* 1972).

6.1.1 Uneven-aged systems

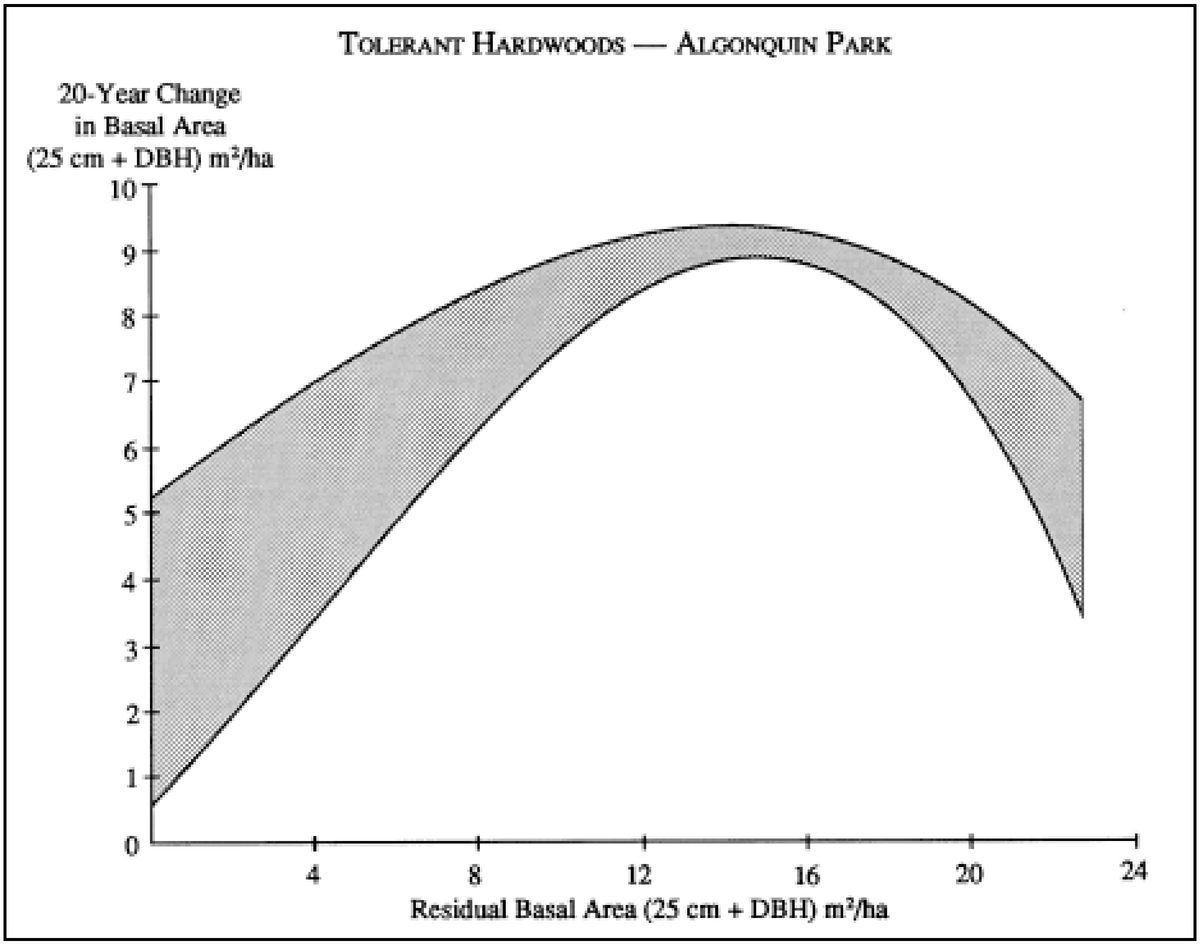
Uneven-aged stands contain trees of three or more ages that are spatially intermixed throughout the stand. In uneven-aged stands it is convenient to consider stocking in terms of total basal area by diameter class groupings (Smith 1986). These are 1) total basal area in trees greater than 1 cm DBH, 2) basal area in trees greater than 9 cm DBH and 3) basal area in trees greater than 24 cm DBH. These represent, either directly or indirectly: 1) recruitment, 2) polewood growing stock and 3) sawlog components.

Depending on species mixture, local site quality and site region, mature hardwood stands can obtain stocking levels averaging about 35 m^2/ha of total basal area. The distribution of this basal area may vary widely among stand components depending on site and, more importantly, stand history. Undisturbed stands usually have much of their basal area in the largest-sized trees and have developed a two-storied appearance. High graded or unmanaged stands may have little basal area in large trees except for cull, because of intense, uncontrolled harvesting of merchantable-sized trees in the past.

TABLE 6.0.1: Stand factors affecting determination of growth and yield in hardwoods (*from*: Schlaegel [1978])	
EVEN-AGED	UNEVEN-AGED
AGE STRUCTURE	
• All trees essentially of same age • Stand age indicates physiological maturity • Age used to determine parameters such as diameter, height, basal area, volume and site index	• Continuous age distribution • Stand age does not exist • Conventional yield tables and growth equations do not work • Number of years since treatment is useful for prediction
DIAMETER DISTRIBUTION	
• normal or skewed-normal distribution • Most trees grouped about the mean • Can use average diameter, range and standard deviation for comparisons • Can use normal probability density function to predict diameter distribution	• Reverse-J-shaped distribution • Average stand diameter cannot be interpreted • Can use exponential or Weibull probability density function • Growth rates predicted by stand table projection by diameter class from permanent sample plots
BASAL AREA	
• Basal area increases to an asymptote • Growth pattern is sigmoid, starting slowly, accelerating, then slowing to a constant	• Basal area nearly constant except for minor fluctuations due to mortality or selective harvesting followed by ingrowth
HEIGHT	
• average height development is sigmoid, increasing to an asymptote • Site index is calculated from dominant trees • Suppressed trees contribute little	• Average height of tallest trees tend to be constant over time • Growth potential of individual trees related to crown vigour and position in canopy • Suppressed trees may be future growing stock

McLean (OMNR 1983) analyzed the 20-year basal area growth of uneven-aged stands in Site Region 5E and found production rate maximized at a residual basal area of about 14 m^2/ha in trees greater than 24 cm DBH (***see*** FIGURE 6.0.1) or 20 m^2/ha in trees greater than 9 cm DBH. At basal areas higher than this the stand is overstocked, usually with larger, mature trees suppressing the smaller sizes. At lower levels, no suppression occurs, but the growing space is under-utilized.

FIGURE 6.0.1: Basal area growth of tolerant hardwoods in Algonquin Park related to residual stocking (OMNR [1983])



For more southerly portions of the tolerant hardwood range in Ontario, such as Site Regions 6E and 7E, the results of the work of Crow *et al.* (1981), Arbogast (1957) and Eyre and Zillgitt (1953) in the Lake States may be more appropriate. Such studies suggest retaining residual basal areas of 16 m^2/ha in trees greater than 24 cm DBH, or 20 m^2/ha in trees greater than 9 cm DBH, for producing high-value products.

In the more northerly portions of the tolerant hardwood range, specifically the Algoma/North shore area of Site Region 4E, provisional work (Rice *et al.* 1997 *in press*) indicates most tolerant hardwood stands are in need of stand improvement cutting to increase stand quality and improve structure. It is recommended that residual stocking after stand improvement cutting be 12 m^2/ha in trees greater than 24 cm DBH with 18 m^2/ha in trees greater than 9 cm DBH. This recommended structure will optimize growth while concentrating it on the size classes with the better quality trees. This recommendation is provisional and work is on-going to verify these figures.

The choice of residual stocking level cannot be set independently but must be considered with reference to the length of the cutting cycle, maximum DBH and expected growth rates to meet sustainability guidelines. The manager might vary the cutting cycle according to the residual stocking level required and the minimum volume to be grown for the next cut. Under all options, longer cycles require lower initial basal area levels. Under economic constraints, for example, the higher costs of roads necessary to access stands may require heavier cutting to justify such costs, resulting in associated lower residual densities and thus longer cutting cycles and reduced annual harvest area. In Site Region 5E initial implementation of uneven-aged management was based on a 20-year cycle. The faster growth rates and better timber quality of stands in Site Regions 6E and 7E are well-suited to a 15-year cycle initially. In Site Region 4E, initial cutting cycles are expected to be longer.

Full stocking should be obtained within two to three cutting cycles (OMNR 1983). Once stands become regulated and quality increases, it may be possible—in fact, preferable—to reduce the length of the cutting cycle. Evidence from good sites in Site Region 5E indicates that cycle lengths of 12 years are feasible.

In some cases, poor trees may be retained for site protection and to encourage improved bole-form of residual crop trees. In badly degraded or abused stands on adequate sites, stocking levels may be chosen below the 'ideal' optimum to accelerate recruitment of better quality trees. In Site Region 5E, residual stocking levels should never be set lower than 11.5 m^2/ha in trees greater than 9 cm DBH and at least 75 per cent of this must be in crop-quality trees (AGS).

6.1.2 Even-aged systems

In *uneven-aged stands* trees of three or more ages are spatially intermixed within the stand and grown continuously without uniform rotation length. Uneven-aged stands and forests are managed by *volume* in terms of specific numbers of trees in each DBH class. In *even-aged stands*, a population of trees of similar age or age class are grown as an entity from establishment to harvest on a specified rotation cycle. A forest comprising a regulated series of even-aged stands is managed in terms of the *areas* and *volume* occupied by specific age classes (stands).

The curve of total growth over time in an even-aged forest is sigmoid in shape, increasing to a maximum, then declining. An unharvested stand, if left long enough, will have net growth that will eventually become negative when mortality exceeds accretion (Bormann and Likens 1979). The peak of the mean annual increment (MAI) is often used to determine rotation age in cases where maximum timber production rate is the prime objective of management. Use of any rotation age other than that shown by the culmination of MAI will result in a lower average rate of production (Clutter *et al.* 1983).

Other objectives, however, may dictate choice of rotation length—for example, specification of product sizes required; maximization of annual net value growth; or maximization of return for specified discount rates. Rotations may be as short as 50 years for fibre products and as long as 200 years where aesthetics are the prime concern (e.g. with hemlock). In hard maple and yellow birch stands, rotations are frequently set at 90 to 120 years, depending on site and intensity of management (Tubbs 1977b).

Rotation lengths can be substantially decreased by appropriate tending and thinning treatments. Normally, even-aged stands are silviculturally treated at frequent intervals to control species composition, eliminate poor quality and accelerate the growth of crop trees. For best growth and quality development, increasing amounts of basal area and decreasing numbers of trees are retained as average stand diameter increases (Erdmann 1987) (***see*** Section 7.0 “Stand Growth and Yield”).

The most commonly used method of density control for even-aged stands is the stocking guide. Stocking guides were first developed by Gingrich (1964, 1967) for upland central hardwoods in the United States. An overview of the stocking guide concept and its use can be found in Ernst and Knapp (1985). Examples of stocking guides and their use are found in APPENDIX D “Hardwood Species Factsheets” and APPENDIX E “How to Use a Stocking Guide”.

In northern hardwood stands of mixed species composition, stocking guides should account for the different growing-space requirements of each species. The concept of *relative density,* which assigns different space requirements to three groups of species based on shade tolerance, may be effectively used. Relative density is computed as a composite of each species’ contribution to the mixture (Stout 1987; Stout and Nyland 1986). Work by Stout *et al.* (1994) is developing relative density guidelines for eastern Ontario mixed-species forests.

6.2 Stand Structure

The manner in which individual trees from seedling to sawtimber sizes are arranged in a stand is termed *structure.* Stand structure represents the distribution of size or age classes in a crop. An ideal structure allows full utilization of growing space and thus maximizes the growth rate that is possible at ideal stocking levels. Typically the relationship of number of trees by diameter class forms a “reverse-J-shaped” curve in uneven-aged stands and a “bell-shaped” curve in even-aged stands.

6.2.1 Uneven-aged systems

A stand on a good site stocked with high-vigour, low-risk trees and having a range of diameters that fully occupies the available growing space would tend to grow at the maximum rate. A balanced structure, with all required size classes present, ensures that there is always a supply of growing trees developing into harvestable products.

In most stands designated for uneven-aged management, two or more cutting-cycles will be necessary to achieve the recommended structure and stocking level of high-quality trees. The difference between the stocking requirement and crop-tree stocking must be made up initially by leaving trees of poorer quality. It is important to realize that this “ideal” condition can never be reached in all parts of the stand at one time, but is the average at which to aim. Through management efforts (i.e. tree-marking), the stand, over time, should contain a progressively greater proportion of acceptable growing stock.

McLean (OMNR 1983) recommended the size-class distribution for tolerant hardwoods managed for high-quality products in uneven-aged systems on a 20-year cycle in Algonquin Park (Site Region 5E). This distribution is recommended for central Ontario. Arbogast (1957) recommended the size-class distribution for uneven-aged management in the Lakes States. This distribution is recommended for southern Ontario. These size-class distributions are shown in TABLE 6.0.2. Provisional work in the Algoma/North Shore area (Rice *et al.* 1997 *in press*) is also shown in this table. Work is on-going to verify these provisional values.

TABLE 6.0.2 : Recommended residual levels by size class for southern Ontario, central Ontario and Algoma/North Shore regions (*adapted from*: Arbogast 1957; Anderson and Rice 1993; Rice *et al.*1997 *in press*)

SIZE CLASSES	SOUTHERN ONTARIO		CENTRAL ONTARIO		ALGOMA/NORTH SHORE[1]	
	m^2/ha	trees/ha	m^2/ha	trees/ha	m^2/ha	trees/ha
Polewood	4	237	6	333	6	274
Small sawlogs	6	69	8	100	8	92
Medium sawlogs	5	42	3	21	2	13
Large sawlogs	5	20	3	12	2	10
TOTALS	**20**	**368**	**20**	**466**	**18**	**389**

[1] Values for the Algoma/North Shore region are provisional and work is on-going to verify these values.

A diagram of the data in TABLE 6.0.2 from central Ontario showing the frequency distribution of diameter classes indicates a “reverse-J-shaped” curve (***see*** FIGURE 6.0.2) whose characteristics are determined by several factors:

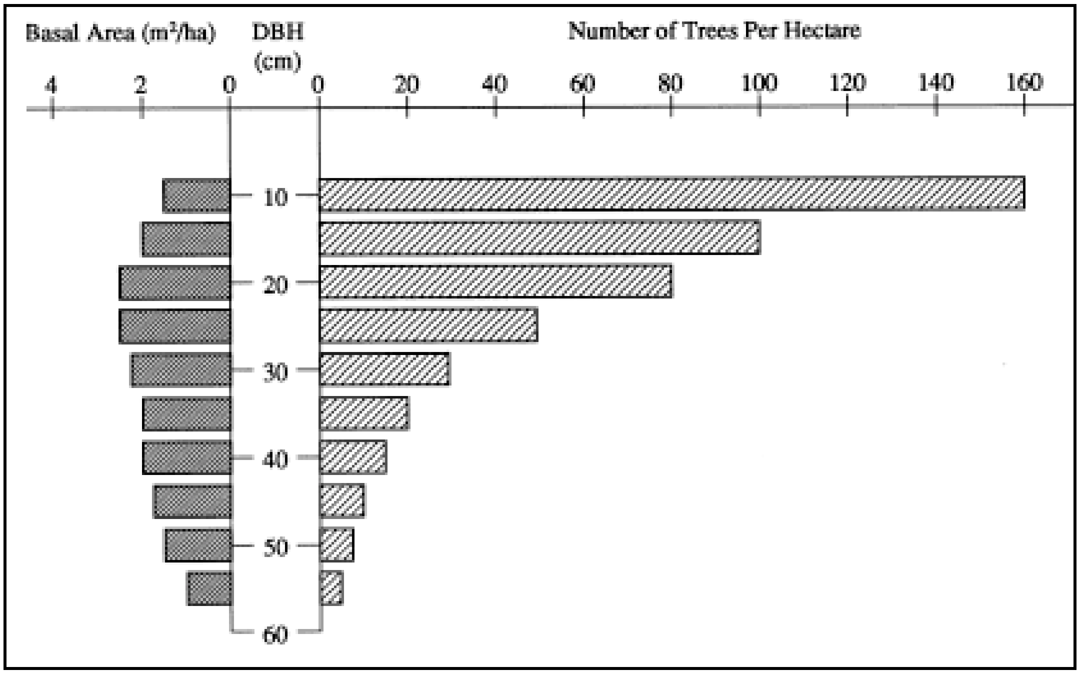
- **Maximum diameter to be retained**: A function of economic maturity as outlined in Section 5.0 “Quality Development in Trees”, and of other factors. In Site Region 5E, a maximum diameter of 60 cm is commonly used for timber production. In Site Region 4E, a smaller maximum diameter may be appropriate. Larger size trees may be maintained in order to meet specific habitat or aesthetic objectives.

- **Stocking level or stand basal area**: Dependent on site potential; commonly set at 20 m^2/ha in trees 9 cm DBH and greater in Site Region 5E

- **Length of cutting cycle**: Reflects site potential and the economics of access and yield expectation; commonly set at 20 years in Site Region 5E

- **Minimum diameter considered**: Reflects merchantability standards; usually set at 9 cm.

FIGURE 6.0.2: Stand and stocking targets recommended for selection management in Algonquin Region (OMNR 1990)



The shape of the frequency distribution of diameter classes reflects the regulated nature of the stand structure. Progressively larger numbers of successively smaller-sized trees are retained to provide recruitment capital to fill gaps created by periodic mature and overcrowded tree removals.

A balanced distribution is exponential and the average quotient between numbers of trees in consecutively smaller (5 cm) DBH classes tends to be constant and was termed a "Q-value" by Meyer (1952). For any distribution, an approximate Q-value can be determined by fitting a straight line to the relationship between the logarithm of frequency of stems to DBH class. Q-value is calculated as the antilog of the product of class interval multiplied by the slope coefficient. The methods described by Tubbs and Oberg (1978), Leak (1963) and Hutnik (1958) may be consulted for additional detail. Smith and Lamson (1982) have published tables of distributions based on varying Q-value, maximum DBH and residual basal area.

Simulation studies have concluded that these parameters should vary depending on the management objectives (Hansen and Nyland 1987). In some cases, a single Q-value may not be adequate to describe the shape of the most productive stand structure. A dynamic Q-value or a more complex function may be more appropriate. A more comprehensive discussion of these options is outlined in *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

Stand structure targets should reflect the potential of the site to produce wood. In Site Regions 6E and 7E, the structure recommended for timber production in the Lake States (Arbogast 1957) is more appropriate than that discussed for Site Region 5E. In FIGURE 6.2.2, the recommended size-class distributions are compared for the former Algonquin Region (Site Region 5E south of the French and Mattawa Rivers) *vs*. the Lake States Region (Northern Michigan).

The two curves differ: Site Region 5E values are lower in sawlog portions and a little higher in polewood portions. This reflects a longer cutting cycle (20 years *vs*.15 years) and somewhat poorer site and growth conditions in Site Region 5E and agrees with recommendations by Eyre and Zillgitt (1953) to reduce sawlog stocking by 15 per cent if cutting cycles are increased by 5 years. The Site Region 5E curve also reflects a lower overall target stocking level (14 m^2/ha *vs*. 16 m^2/ha in trees greater than 24 cm), to allow stands to grow an additional five years without becoming overstocked. The difference in relative shape of the curves is also reflected in their different Q-values (Site Region 5E = 1.46 and Lake States = 1.32 for 5 cm DBH classes).

Similarly, Q-values set for tolerant hardwood stands in the northern transitional forest may need to reflect more limited site potential. Work is progressing in this area.

Stands managed under the group-selection system may use the same guidelines as those for single-tree selection, although cultural work in the understory (for regeneration purposes) will not benefit stand production appreciably (Leak and Gottsacker 1985).

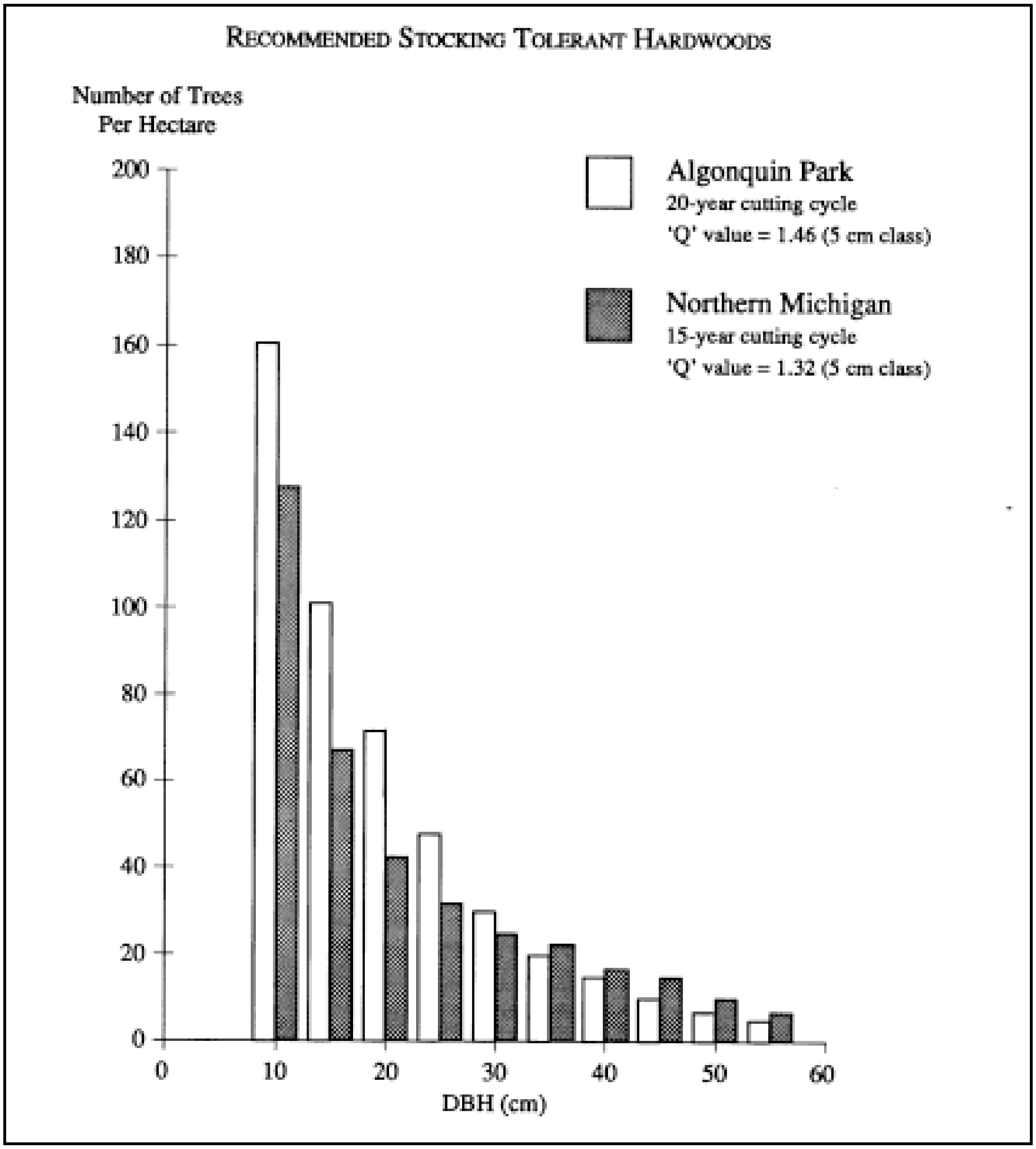
6.2.2 Even-aged systems

Even-aged stands tend to be composed of trees of similar size, creating a size-class distribution or structure that tends to plot as a normal or bell-shaped curve (***see*** FIGURE 6.0.4). However, a forest composed of many even-aged stands of varying age managed in a regulated series will exhibit a reverse-J-shaped curve rather than a normal one (Smith 1986).

Methods for optimizing residual diameter class distributions for thinning even-aged stands have been developed by Roise (1986), using a non-linear programming algorithm. Similarly, Chen *et al.* (1980) demonstrated the use of dynamic programming to optimize stand density over time for even-aged stands.

Stand structure is greatly influenced by the type of thinning or intermediate cutting employed: crown thinning (from above), low thinning (from below), selection thinning, or mechanical thinning (Erdmann 1987). Studies in which plots were cut to constant density, but by different methods to yield a variety of structures, showed that plots cut from above had negative growth for the first five years after thinning, while plots cut from below had many dominant and codominant stems that grew very well. Trees that were growing best before thinning are the ones to leave as residuals to optimize stand growth (Stout 1987). This means that crop trees generally should be chosen from the upper half of the diameter range (Roach and Gingrich 1968). Cutting primarily from below will open the canopy sufficiently to stimulate a growth response in the residual upper-canopy trees.

FIGURE 6.0.3: Comparison of stand structures recommended for selection management of tolerant hardwoods in Algonquin Region (OMNR 1983) and in the Lake States (Arbogast [1957]) (OMNR 1990)

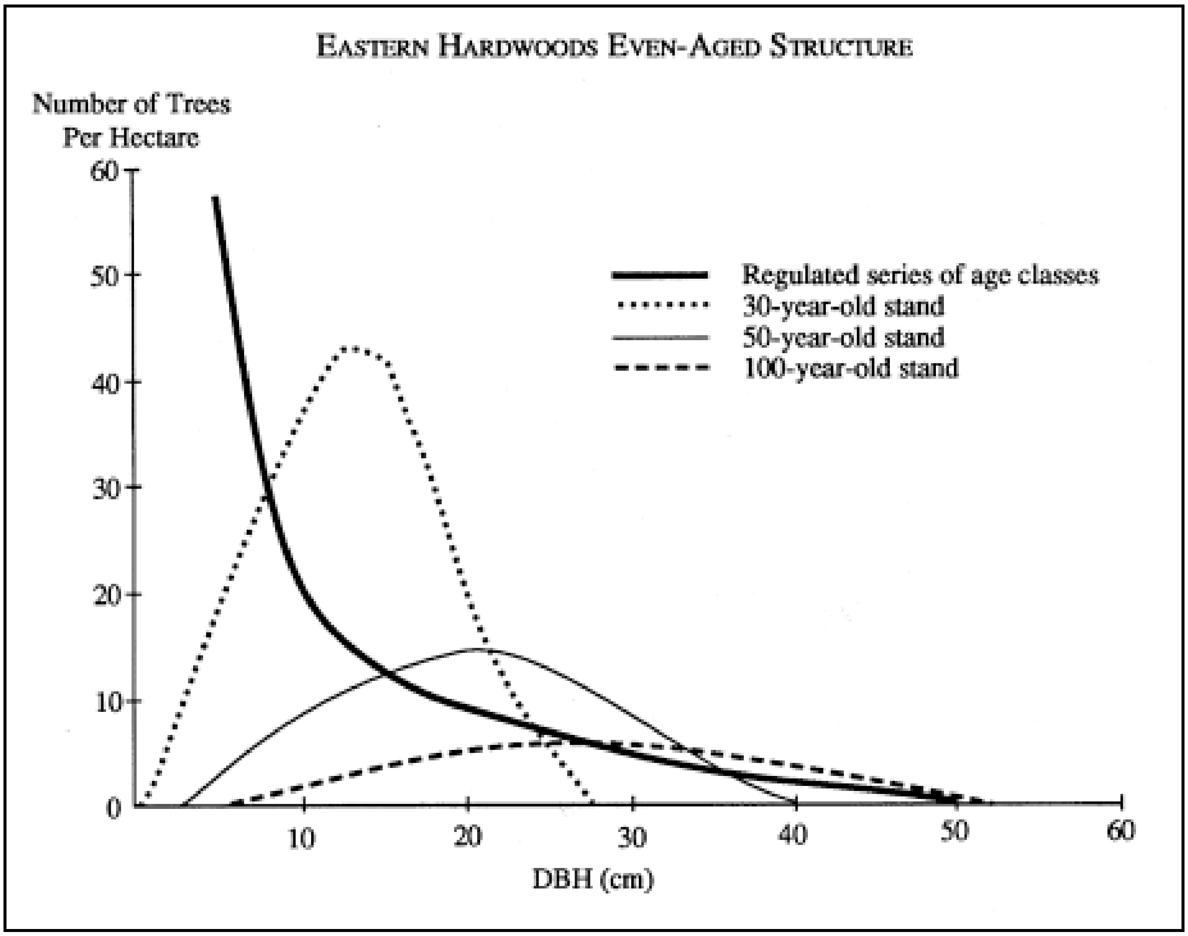


Gingrich (1967) studied the structure of upland hardwoods in the central United States and found that young stands exhibited moderately skewed (positive) diameter distributions, which tended to normalize as the stands grew older. He concluded that stand structure could be ignored in the appraisal of stocking and that it had only a minor effect on volume growth.

In a regulated stand, basal area and volume growth on a given area should not vary, with either system, to any extent over a wide range of residual densities. Within this range, stand structure can be manipulated to provide the kind of growth needed by management (Jacobs 1968). For example:

- increase density to improve tree quality
- decrease density to accelerate diameter growth
- for tolerant species, decrease density to transfer growth to the sapling portion of the stand.

FIGURE 6.0.4: Stand structure and forest structure developed under regulated even-aged system (*from*: Smith [1986])



7.0 STAND GROWTH AND YIELD

7.0 Stand Growth and Yield

by Murray Woods, James Rice and Eric Boysen

Growth and yield estimates 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, resource managers can examine the probable effects of various silvicultural decisions (e.g. cutting intensity, harvest scheduling, etc.) on the long-term sustainability of the forest resource.

While the trend in the "study" of growth and yield is to the development of computer *growth models*, traditional growth and yield tools 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, 4) stocking guides and 5) cull tables. The application and relationship of each of these tools is shown in FIGURE 7.0.1.

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 presented 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 7.0.1.

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:

- definitions of growth and yield terms (*based on:* Haddon 1988)
- 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
- procedures for using some of the management decision tools.

Definitions related to the terminology used in this discussion of growth and yield methods and products are provided in TABLE 7.0.2 (Haddon 1988).

FIGURE 7.0.1: Growth and yield prediction

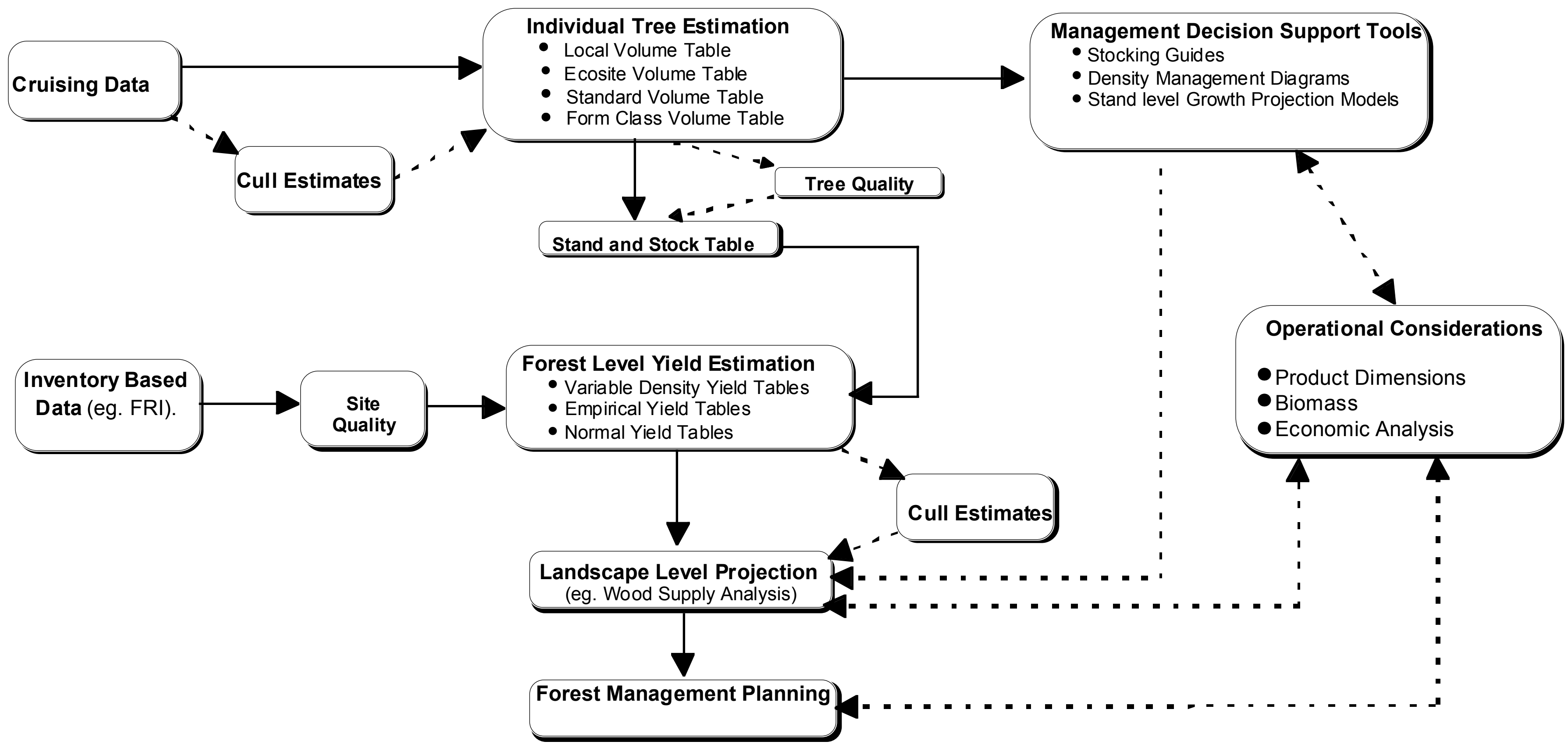


TABLE 7.0.1: Growth and yield sources

	Growth and Yield Tools	Hard Maple	Yellow Birch	Red Oak	White Ash	Black Cherry	American Beech	Basswood	Hemlock	White Birch	Trembling Aspen	Red Maple
Site Productivity	Site Index	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)	(Frothingham 1915)	(Carmean 1978)	(Carmean 1978)	(Carmean 1978)
	Site Class	(Plonski 1974)	(Plonski 1974)				(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)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	(Honer *et al.* 1983)	
	Form Class Volume Table[1]	(Berry 1981)	(Berry 1981)	(Berry 1981)	(Berry 1981)	(Berry 1981)	(Berry 1981)	(Berry 1981)		(Berry 1981)	(Berry 1981)	
	Cull Estimates	(*from:* Morawski *et al.* 1958)	(*from:* Morawski *et al.* 1958)	(*from:* Basham 1991)			(*from:* Basham 1991)	(*from:* Basham 1991)	(*from:* Basham 1991)	(*from:* Basham 1991)	(*from:* Basham 1991)	(*from:* Basham 1991)
Forest Level Estimation/ Forecasting	Normal Yield Tables	(Plonski 1974)	(Plonski 1974)				(Plonski 1974)			(Plonski 1974)	(Plonski 1974)	
	Variable Density Yield Tables											
	Empirical Yield Tables											
	Computer Simulators	(Solomon *et al.* 1995)										
Management Decision Support	Stocking Guides	(Tubbs 1977)	(Crow and Erdman)	(*from:* McGill *et al.* 1991)	(Crow and Erdman)		(Erdman 1986)	(Crow and Erdman)	(Tubbs 1977)	(Marquis *et al.* 1969)		(Erdman *et al.* 1985)

[1] Form Class 79 is an accepted FC table for all "heavy" hardwoods in Ontario

TABLE 7.0.2. Definitions of common growth and yield terms	
TERM	DEFINITION
Basal Area	1) Of a tree, the area in square metres of the cross section at breast height of the stem. 2) Of a stand, the area in square metres per hectare of the cross section at breast height of all the trees.
Diameter at Breast Height (DBH)	The stem diameter of a tree measured at breast height (1.3 metres above ground level). Unless otherwise stated, applies to the outside-bark dimension.
Growth	The increase in diameter, basal area, height or volume of individual trees or groups of trees during a given period.
Increment	*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.
Quadratic Mean Diameter (DBHq)	Diameter of the tree of average basal area.
Site Class	An objective classification of site productivity into several classes.
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), of dominant and codominant trees in a stand. Used for even-aged stands.
Stand Density	The number of trees usually expressed on a per hectare basis.
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.
Stocking	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.
Top Height	The mean height of 100 trees per hectare of largest diameter at breast height.

TABLE 7.0.2. Definitions of common growth and yield terms	
TERM	DEFINITION
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.
Yield	Growth or increment accumulated by trees at specified ages expressed by volume or weight to defined merchantability standards.
Yield Curve	A graphical or mathematical representation of the yield of a given species, on a given site, at a given time.
Yield Table	A summary table 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.

7.1 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, influences 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 ash 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 required as an input value for many of the growth models that have been developed in the United States (e.g. Fiber 3.0 [Solomon *et al.* 1995], SILVAH [Marquis and Ernst 1992] and NE-TWIGS [Belcher 1992], etc.). These estimates of site productivity are 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 D.

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 handfitting a curve through individual height-age measurements for multiple plots per species. Using this first curve as a guide curve, curves of the same shape were drawn one standard deviation above and below to create the boundaries of the site classes. Plonski's curves are *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.

SITE FORM

Whereas height at an index age (SI) provides a relative measure of potential site productivity in even-aged stands, the approach is incompatible in *uneven-aged* stands where harvesting using the selection system produces a range of stand ages. Vanclay and Henry (1988) used a Site Form (SF) approach to characterize potential productivity in uneven-aged forests. Site form is a measure of height at a selected index diameter (DBH) and varies according to species. For example, using an index diameter of 25 cm in an uneven-aged hard maple stand, an unsuppressed tree (or reading the value from a stand-specific height-diameter curve) of 14 m would yield a SF of 14. Site productivity can be efficiently estimated using the height-diameter relationship, which is derived from field data. It is relatively insensitive to fluctuations due to harvesting, as it remains constant over long periods of time. Site form has been shown to be strongly correlated with basal area and periodic volume increment in some studies (Vanclay 1988). Although it was most effective in single-species stands, the inclusion of several other species did not appear to influence estimates.

A provisional site form diagram and table has been developed for uneven-aged hard maple stands (APPENDIX D) based on Ontario conditions. However, further testing of this method is needed for classifying potential productivity in Ontario tolerant hardwood stands managed with partial harvesting systems.

7.2 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 each type of volume table is presented in TABLE 7.2.1.

Form-class volume tables have been used in Ontario for over 60 years (Anon. 1930, 1948). They were used to estimate total and merchantable yields of individual trees, or sections of trees and were usually based on Smalian's formula. In Ontario, Form-Class 65, 70, 75 and 79 volume tables have been used for a variety of species (Berry 1981a; Staley 1991). The Form-Class 79 volume table has been tested throughout Ontario's tolerant hardwood forests and it is the preferred volume table for estimating the volume of standing timber (APPENDIX C). Total fuelwood volume in the remaining tops is estimated by multiplying the form-class volume estimate by 0.8 (Staley 1991).

TABLE 7.2.1: Input requirements for various types of volume tables

TYPES OF VOLUME TABLES	REQUIRED INPUTS							
	Species	DBH	Total Height	Merchantable Height	Stump Height	Top Diameter	Age	Cul 1%
Local Volume Table	r	r						
Form Class 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

The calibration of form-class tables for local conditions requires measures 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 then 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 of ecosites it occupies. Honer's (1967) sampling was done throughout Canada. Standard volume tables for each species covered in this guide are presented with their respective fact sheets in APPENDIX D.

Local volume tables are a modification of standard volume tables based on the area's species DBH-height relationship. 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.

7.3 Forest Level Estimation and Forecasting

YIELD TABLES

Yield tables for *even-aged* stands are one of the oldest tools for estimating yields. Early yield tables only provided volume estimation, at different ages, for a given forest unit. Modern tables often include stand height, mean diameter, number of stems, stand basal area and current and mean annual volume increments, in addition to accumulated volume estimates (i.e. yield). 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 volume are good enough to plan both the timing and marketing of the harvest (Philip 1994).

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

Normal yield tables (e.g. Plonski 1960, 1981) provide estimates of expected yields tabulated by stand age and site index (or grouped into site classes) for ideal, fully stocked or "normal" forest stands (Vanclay 1994). They are usually derived by combining temporary sample plot data and stem analysis. The volume of an existing stand may be estimated with a normal yield table by adjusting the published yield values by a percentage of the expressed normality (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* hardwoods 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 7.3.1 and the *Yield Estimates* by site type are presented in TABLE 7.3.2. This table also presents some generalized growth and yield estimates for comparison purposes. Ecosite yield estimates for managed and unmanaged tolerant hardwood stands in Central Ontario are presented in TABLE 7.3.3. Continued long-term monitoring of growth rates is required.

Empirical yield tables are similar to normal yield tables in their construction and use. The difference is that empirical tables are based on sample plots of average rather than full stocking. According to Husch *et al.* (1972), "the 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. Variable density yield tables do not exist for tolerant hardwood stands in Ontario.

Stand and stock tables are quantitative descriptions of individual or groups of forest stands for forest inventory purposes. This approach is used to estimate the amount of useable wood for a variety of end-products, including pulpwood, fuelwood, or sawtimber. 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 by diameter class and quality class.

A *stand table* is used to present the number of trees by species for a forest, with data often expressed as basal area by diameter, quality or height classes. Stand tables may express information 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 (e.g. Raymond and McLean 1984) use this method of stand growth projection.

TABLE 7.3.1: Hardwood ecosite productivity classes by soil type (based on FEC plot data)

	SOIL TYPE								
	S1	**S3**	**S4**	**S5**	**S6**	**S7**	**S9**	**S10**	
	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	Shallow - Deep MR: 6 Coarse Loamy Silty	Shallow - Deep MR: 2 - 5 Fine Loamy - Clayey	**Productivity**
hard maple[1]		24.1 26.1 24.2 29.1 27.1 28			24.2 **25.2** **35*** 27.2 28.2 29.2				**High**
yellow birch		27.1 28.1* 29.1			28.2 29.2 30.2	29.2			
American beech				25.2*	28.2 25.2*				**Medium**
red oak	23. 14.	23.1 24.1* 14.1			14.2				
white ash	no data	no data	no data	no data	no data	no data	no data	no data	Low
black cherry	no data	no data	no data	no data	no data	no data	no data	no data	
white birch		27.1 17.1			17.2* 18.2 24.2 27.2				
basswood	no data	no data	no data	no data	no data	no data	no data	no data	
red maple	no data	no data	no data	no data	no data	no data	no data	no data	
eastern hemlock	28. 30.	28.1 30.1			28.2				
trembling aspen		18.1* 19.1 27.1	18.2*	18.2*	35* 17.2* 18.2	18.2	**34**	**35*** 34* 1	

[1] Productivity estimation for uneven-aged hard maple stands based on an evaluation of the range of Site Form sampled. **H** => SF 22 / **M** = SF 16 to SF 21 / **L** =< SF15
* Preliminary Site Index assessment based on limited data.

TABLE 7.3.2: Yield estimates by productivity classes and ecosite-soil types for even-aged hardwood species (based on FEC plot data)

	SI Range[1]	Hard Maple[+] Ecosite-Soil Type	40 yrs MAI (m³/ha/yr)	40 yrs Yield (m³/ha)	60 yrs MAI (m³/ha/yr)	60 yrs Yield (m³/ha)	80 yrs MAI (m³/ha/yr)	80 yrs Yield (m³/ha)	100 yrs MAI (m³/ha/yr)	100 yrs Yield (m³/ha)
High	>=14	no data available	2.5	101	2.9	172	3.0	236	2.9	290
Medium	11-13	no data available	2.0	81	2.4	143	2.4	196	2.4	237
Low	<=10	no data available	1.6	62	1.9	113	2.0	158	1.9	193

	SI Range[1]	Yellow Birch Ecosite-Soil Type	40 yrs MAI (m³/ha/yr)	40 yrs Yield (m³/ha)	60 yrs MAI (m³/ha/yr)	60 yrs Yield (m³/ha)	80 yrs MAI (m³/ha/yr)	80 yrs Yield (m³/ha)	100 yrs MAI (m³/ha/yr)	100 yrs Yield (m³/ha)
High	>=14		2.5	101	2.9	172	3.0	236	2.9	290
Medium	11-13	27.1-S3*, 28.1-S3, 28.2-S6, 29.1-S3, 29.2-S6, 29.2-S7, 30.2-S6	2.0	81	2.4	143	2.4	196	2.4	237
Low	<=10		1.6	62	1.9	113	2.0	158	1.9	193

	SI Range[1]	American Beech Ecosite-Soil Type	40 yrs MAI (m³/ha/yr)	40 yrs Yield (m³/ha)	60 yrs MAI (m³/ha/yr)	60 yrs Yield (m³/ha)	80 yrs MAI (m³/ha/yr)	80 yrs Yield (m³/ha)	100 yrs MAI (m³/ha/yr)	100 yrs Yield (m³/ha)
High	>=14	25.2-S5*, 28.2-S6	2.5	101	2.9	172	3.0	236	2.9	290
Medium	11-13		2.0	81	2.4	143	2.4	196	2.4	237
Low	<=10	25.2-S6*	1.6	62	1.9	113	2.0	158	1.9	193

	SI Range[1]	Red Oak Ecosite-Soil Type	40 yrs MAI (m³/ha/yr)	40 yrs Yield (m³/ha)	60 yrs MAI (m³/ha/yr)	60 yrs Yield (m³/ha)	80 yrs MAI (m³/ha/yr)	80 yrs Yield (m³/ha)	100 yrs MAI (m³/ha/yr)	100 yrs Yield (m³/ha)
High	>=14	23.1-S1, 23.1-S3*, 24.1-S3	2.5	101	2.9	172	3.0	236	2.9	290
Medium	11-13	14.1-S1*, 14.1-S3, 14.2-S6	2.0	81	2.4	143	2.4	196	2.4	237
Low	<=10		1.6	62	1.9	113	2.0	158	1.9	193

	SI Range[1]	White Birch Ecosite-Soil Type	40 yrs MAI (m³/ha/yr)	40 yrs Yield (m³/ha)	60 yrs MAI (m³/ha/yr)	60 yrs Yield (m³/ha)	80 yrs MAI (m³/ha/yr)	80 yrs Yield (m³/ha)	100 yrs MAI (m³/ha/yr)	100 yrs Yield (m³/ha)
High	>=17	17.2-S6, 18.2-S6, 24.2-S6*, 27.1-S3, 27.2-S6	3.7	147	3.7	220	3.1	250		
Medium	14-16	17.1-S3	3.0	118	2.8	170	2.3	186		
Low	<=13		2.4	94	2.3	137	1.8	145		

TABLE 7.3.2: Yield estimates by productivity classes and ecosite-soil types for even-aged hardwood species (based on FEC plot data)

	SI Range	Eastern Hemlock** 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		(2.5)	(101)	(2.9)	(172)	(3.0)	(236)	(2.9)	(290)
Medium	10-13	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)

	SI Range[1]	Trembling Aspen 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	>=22	17.2-S6, 18.2-S4*, 18.2-S5*, 18.2-S6, 34-S9, 35-S6*, 35-S10*	6.1	245	6.2	371	5.5	438	4.6	459
Medium	18-21	18.1-S3, 18.2-S10, 19.1-S3, 27.1-S3*, 34-S10*	5.0	199	5.2	312	4.6	368	3.8	384
Low	<=17	18.2-S7	3.2	129	3.7	222	3.3	265	2.7	271

	SI Range**	White Ash/Black Cherry/Basswood/Red Maple** 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	No Data Available	2.5	101	2.9	172	3.0	236	2.9	290
Medium	11-13	No Data Available	2.0	81	2.4	143	2.4	196	2.4	237
Low	<=10	No Data Available	1.6	62	1.9	113	2.0	158	1.9	193

Notes:
1 SI ranges & yields from Plonski (1974).
+ No even-aged FEC plot data available.
* Preliminary Site Index assessment based upon limited data.
** SI ranges & yields from Plonski (1974) tolerant hardwoods.

TABLE 7.3.3: Uneven-aged yield estimates (10 cm+) by ecosite types - managed and unmanaged

	Geographic Location			Managed Stand Increment			Unmanaged Stand Increment		
Ecosite[1]	District	Township	Data Set Reference	Basal Area MAI m²/ha/yr	GTV MAI m³/ha/yr	Number of Years MAI is based on	Basal Area MAI m²/ha/yr	GTV MAI m³/ha/yr	Number of Years MAI is based on
23.1 & 23.2									
24.1 & 24.2	Parry Sound	East Mills	Algonquin Growth Study Plots[2]	0.38	3.72	5	0.44	4.17	15
	Parry Sound	Wilson	Algonquin Growth Study Plots[2]				0.34	3.4	10
	Bancroft	Anstruther-N	Algonquin Growth Study Plots[2]	0.46	4.46	5	0.15	1.33	12
	Bancroft	Anstruther	Algonquin Growth Study Plots[2]				0.51	5.08	10
	Parry Sound	Laurier	Trout Creek[3]	0.34[4]	3.62[4]	22			
	Algonquin Park	Sproule	Little McCauley Lake[5]	0.64[4]	5.32[4]	28	0.45	4.30	28
25.1 & 25.2	Bancroft	Anstruther-S	Algonquin Growth Study Plots[2]	0.53	4.10	7	0.23	2.99	10
	Parry Sound	Ballantyne	Algonquin Growth Study Plots[2]	0.42	3.94	5	0.48	4.28	12
	Parry Sound	Oakley	Algonquin Growth Study Plots[2]	0.40	4.06	5	0.14	1.23	12
	Algonquin Park	Peck	Algonquin Growth Study Plots[2]	0.42	4.02	5	0.53	4.86	12
	Algonquin Park	Preston	Algonquin Growth Study Plots[2]	0.36	3.64	5	0.57	5.68	12
	Algonquin Park	Peck	Swan Lake Marking Plots (11.7 cm+)[6]				0-net growth	0-net growth	30
	Algonquin Park	Peck	Stand Density Plots[7]	0.44	4.54	18	0-net growth	0-net growth	19
26.1 & 26.2									
27.1 & 27.2									
28.1 & 28.2	Algonquin Park	Hunter	Algonquin Growth Study Plots[2]	0.28	2.70	5	0.22	1.40	12
	Parry Sound	McClintock	Algonquin Growth Study Plots[2]	0.40	3.86	5	0.16	3.35	10
	Algonquin Park	Nightengale	Algonquin Growth Study Plots[2]	0.44	4.10	5	0.20	2.16	5
	Parry Sound	Proudfoot	Algonquin Growth Study Plots[2]	0.40	3.78	5	0.57	4.89	12
	Algonquin Park	Dickson	Algonquin Growth Study Plots[2]	0.46	4.38	5	0.18	1.98	5
	Algonquin Park	Peck	Parkside Bay[6]	0.37	3.51	7	0.40	7.67	7
	Algonquin Park	Lawrence	Louisa Flats Plots[8]	0.46	4.56	10			

TABLE 7.3.3: Uneven-aged yield estimates by ecosite types - managed and unmanaged

	Geographic Location			Managed Stand Increment			Unmanaged Stand Increment		
Ecosite[1]	District	Township	Data Set Reference	Basal Area MAI m^2/ha/yr	GTV MAI m^3/ha/yr	Number of Years MAI is based on	Basal Area MAI m^2/ha/yr	GTV MAI m^3/ha/yr	Number of Years MAI is based on
29.1 & 29.2	Sault Ste. Marie	Wishart	Turkey Lakes[9]				0-net growth	0-net growth	10
	Sault Ste. Marie	Algoma Area	Silvicultural Calibration Plots[10]	0.34[11]	N/A	20			
30.1 & 30.2									
34									
35									

[1] Ecosite Determination based on Species Cover-type
[2] McLean 1987c
[3] McLean 1987a
[4] Even-aged management
[5] McLean 1987b
[6] Anderson and Rice, (Unpublished data)
[7] Rice, Unpublished data
[8] Mihell, Unpublished data
[9] Morrison (*in press*), Canadian Forest Service
[10] Rice *et al.* (*in press*) Back projection technique of increment core sampling

7.4 Simulation of Stand Development and Yield

In recent years, normal yield tables, with their inherent difficulties in defining normality and the lack of a clear relationship to managed stands, have been replaced by simulation modelling techniques. These approaches are more flexible because they can use a variety of stand attributes in the estimation and projection of stand characteristics.

Many simulation models have been developed for the tolerant hardwoods, or they offer methodologies that may be applicable to this forest type. They include comprehensive timber management strategy models (Shifley 1987, 1982; Brand 1981; Simpson *et al.* 1995), models for individual oak species (Hilt 1985a) and mixed hardwoods (Marquis and Ernst 1992; Marquis 1986), integrated ecological models (Rennolls and Blackwell 1986; Kimmins and Scoullar 1984; Aber *et al.* 1982; Botkin *et al.* 1972) multiple resource models (Ffolliott *et al.* 1984) and economic models to evaluate silvicultural options (Mitchell 1988).

Growth and yield models for tolerant hardwood stands are available for even-aged (Solomon and Leak 1986; Miller and Woods 1989) and uneven-aged management (Boothby and Buongiorno 1985; Hansen 1984; Raymond and McLean 1984; Moser *et al.* 1979). Some models can be used for either *even-aged* or *uneven-aged* situations (Solomon *et al.* 1995; Marquis and Ernst 1992; Belcher 1992; Ek and Monserud 1979).

Even-aged models give yield estimates as a function of stand age, whereas models used in uneven-aged situations are based on functional relationships between yield and tree size distribution. The majority of modelling efforts in tolerant hardwoods have been undertaken in the United States. Three of these models, Fiber 3.0 (Solomon *et al.* 1995), SILVAH (Marquis and Ernst 1992) and NE-TWIGS (Belcher 1992) were tested by Bankowski *et al.* (1995a, 1995b, 1996) on Ontario tolerant hardwood stand conditions. Long-term data sets, covering as wide a geographic spread as possible, were used to validate the models. TABLE 7.4.1 (Bankowski, *personal communication*) summarizes the strengths of the tested models.

TABLE 7.4.1: Recommended existing growth and yield models for specific stand attributes in Ontario tolerant hardwood forests

STAND CHARACTERISTIC	5-YEAR PREDICTION	>5-YEAR PREDICTION
Diameter Distribution	Fiber	SILVAH
Total Stand Density	NE-TWIGS/Fiber	NE-TWIGS/Fiber
Quadratic Mean Diameter	NE-TWIGS/Fiber	NE-TWIGS/Fiber
Total Basal Area	NE-TWIGS	NE-TWIGS
Total Stand Volume	Fiber	Fiber
Pole Class Basal Area	Fiber	Fiber
Small Sawlog Basal Area	Fiber	Fiber
Medium Sawlog Basal Area	Fiber	Fiber

Ontario has developed a prototype tolerant hardwood model for *uneven-aged* management (Raymond and McLean 1984) based upon permanent sample plot data. The model has been tested in the former OMNR Algonquin Region and performed adequately in simulating the growth of tolerant hardwood stands managed under the selection system. This model accurately (<10 per cent error) estimated stem frequency, basal area and volume for cutting cycles up to 15 years. Future development of this model will involve calibrating it for areas throughout the range of tolerant hardwoods in Ontario and for ecosites within a region.

A second projection system has been developed in Ontario by Miller and Woods (1989). It is applicable primarily in Site Regions 5E and 6E to unmanaged, undisturbed hard maple stands, showing a relatively small range of ages. These stands are primarily "second growth", having developed after severe disturbances occurring during the past 100 years. This provisional model gives good prediction (<15 percent error) when applied to stands similar in nature to the original sample (i.e. undisturbed second growth).

7.5 Management Decision Support

STOCKING AND DENSITY CONTROL

Stand density largely influences stand growth. Gross stand volume growth is fairly constant over a considerable range of stand densities and ages, but net stand growth (gross growth less mortality) may decrease as stand density increases (Ernst and Knapp 1985). Silvicultural practices are used to change stand structure according to management objectives. For example, thinning can redistribute stand growth to the remaining trees, producing large diameter trees in a shorter period than if the stand were left unmanaged.

The primary objectives of silvicultural thinning practices are:

- maintain stand health
- salvage trees at risk of mortality, increasing total yields over the stands rotation
- increase the growth rates of the individual trees remaining
- achieve desired quality and species composition.

When developing thinning prescriptions, resource managers need information on current stand density to determine the desired residual stand conditions needed for optimal stand growth.

Absolute measures of stand density are meaningful for comparing stands of the same age, species composition and structure on similar sites. However, when any or all of these variables differ, comparison of absolute stand density is less meaningful. The concept of relative stand density has been developed to provide meaningful comparisons among stands that differ in average tree size, age and site. Relative stand density has been described as "...the ratio of the measured absolute density of a given stand to some reference level specific to that forest type" (Ernst and Knapp 1985). It is a method of describing the degree of crowding or competition in an individual stand and comparing it with others even though they may differ in species composition, age or stand size.

Stocking level also implies a stand management objective. A stocking level is expressed as the residual relative stand density that is required to meet the stated management objective (for example, to produce a stand with an average diameter of "x" cm by year "y"). When stand density is subjected to partial harvesting or thinning operations, the observed biological responses are the basis for defining a number of residual density levels. These could include levels that achieve:

- maximum DBH growth of individual trees
- maximum basal area growth
- maximum volume growth
- maximum quality or product development
- maximum development of regeneration
- maximum development of understory wildlife food
- maximum seed production
- minimum levels of windthrow
- minimum levels of damage by insects and diseases.

Management considerations include economic factors and the expected biological response of stands to treatment. Undisturbed stands show a consistent pattern of development, or growth and tend to respond in a consistent way. Economically, factors such as stand accessibility, market conditions, product size and other factors impact on the choice of thinning regimes.

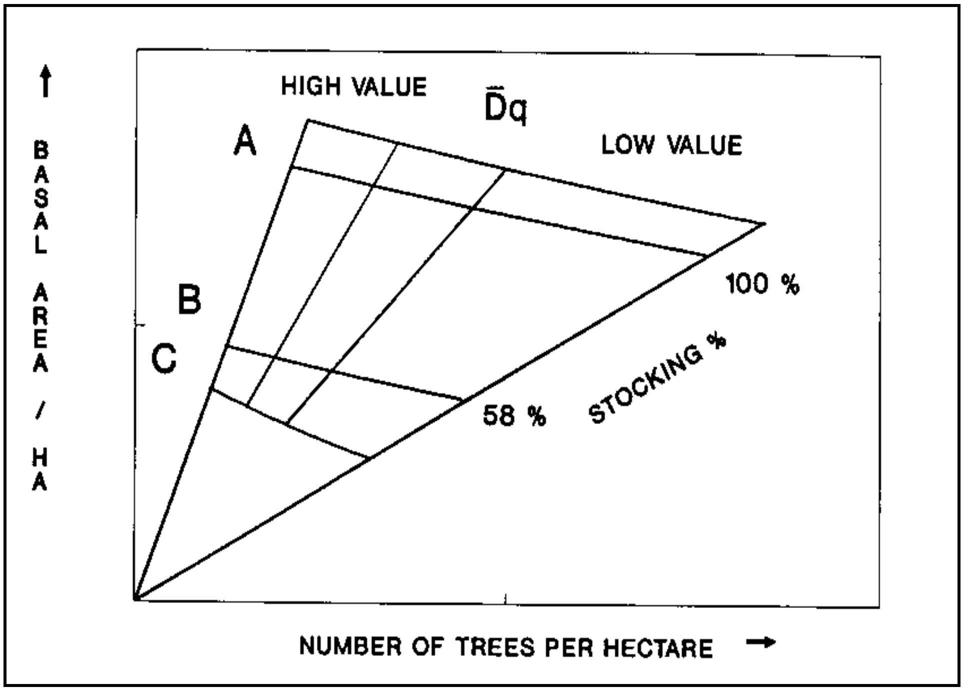
STOCKING GUIDES

Even-aged stocking guides have been developed for most of the major forest species in North America. To-date, most of this work has been completed in the United States. Gingrich's (1967) guide has been adopted as the United States National Forest standard for stocking guides because of its ease of use. Metric presentations of this format are included in the species fact sheets in APPENDIX D.

Gingrich's format presents basal area, number of trees and quadratic mean diameter to illustrate how available growing space is being utilized by trees (***see*** FIGURE 7.0.2). Stocking charts can be used to visualize stand dynamics as stands mature or respond to silvicultural intervention and to formulate silvicultural prescriptions in stands managed under an *even-aged* system.
The "A" line (100 per cent stocking) "...represents a normal condition of maximum stocking for undisturbed stands...of average structure" (Husch *et al.* 1972) and the "B" line represents the lower limit of stocking for full site occupancy (Gingrich 1967). The range of stocking between the

“A” and “B” line is called the zone of “full stocking” because all available growing space is occupied by trees. For stands falling outside this zone, gross increment will be less than maximum because they are either overstocked or understocked.

FIGURE 7.0.2: Simplified example of a stocking guide



Further guidance on the actual use of a stocking guide in the development of a prescription is provided in APPENDIX E.

8.0 GENETICS

8.0 Genetics

by Harvey Anderson and Cathy Nielsen

Many species in tolerant hardwood forests show evidence of racial variation, especially in terms of *photoperiodic* or *geographic* ecotypes. For example, Kriebel (1957) established that hard maple comprised three ecotypes, with the northern one exhibiting better apical dominance and resistance to winter injury but greater susceptibility to drought and leaf insolation injury, compared to more southerly ecotypes. The amount of winter chilling required by northern populations of sugar maple is greater than southern populations and without adequate chilling, growth is not normal the following spring (Kriebel and Wang 1962). Sub-populations of sugar maple have also diverged in leaf morphology and photosynthetic rate along the short gradients of elevation (Ledig and Korbobo 1983).

Other characteristics are related to “clinal” or continuous trends over the species’ range. Both yellow birch and hard maple, for example, show such a correlation in dates of initiation and cessation of growth and leaf abscission. This variation emphasizes the importance of using appropriate seed-zone sources for artificial regeneration.

Overviews of some genetic features of tolerant hardwood forest species are found in Kriebel and Gabriel (1969) and Kriebel (1957) for hard maple, Wearstler and Barnes (1977) and Clausen (1973) for yellow birch, Gall and Taft (1973) and Cech (1971) for red oak, Wright (1944) for white ash, Pitcher (1982) for black cherry and Fowells (1965) for all seven principal species. A summary of genetic diversity of sugar maple, red oak, yellow birch, white ash and black cherry can be found in Li *et al.* (1992).

8.1 Genetic Conservation

Genetic variation is the basis for evolution. Without genetic variation, species cannot adapt to short-term and long-term environmental change. One of the considerations in the application of silvicultural treatments to hardwood stands is the maintenance of genetic variation of each species on the site.

Provenance testing completed in the past and recent genecology studies completed at the Ontario Forest Research Institute have shown some tree species are genetically fine-tuned to the conditions of the environment in which they grow and therefore have a complex structure of locally adapted populations (Ledig 1992). It is important to maintain healthy populations of each species in a variety of environmental conditions to avoid local extirpation of a species.

This becomes particularly critical at the edge of a species range where genetically unique populations may exist and populations are vulnerable to extirpation due to naturally lower population levels. The following considerations should be addressed in the genetic management of any stand:

- be aware of the species which are uncommon in the site district where the stand is located, particularly for species that are at the edge of their natural range (refer to botanical range maps in FIGURE 2.1.2)

- note species of concern and determine the population levels in adjacent stands within pollination distance

- when species of concern exist as isolated populations, ensure retention of healthy populations within the stand and modify prescriptions to encourage regeneration.

Healthy, viable populations require enough trees to avoid inbreeding. Inbreeding may result in inbreeding depression, which manifests itself in the form of lower seed set, reduced vigour of seedlings and reduced resistance to pests.

The number of trees of a particular species that must be retained within the stand to provide a healthy viable breeding population increases when the trees are separated by a distance large enough to prevent breeding with trees of the same species in another stand. Few pollination distances have been determined for hardwoods. However, it can be assumed that the effective pollination distance for wind-pollinating species such as white ash is approximately 100 metres. It should be noted that black cherry, red maple, basswood, American mountain-ash, showy mountain-ash, pin cherry and staghorn sumac are insect-pollinated species. Sugar maple is both insect- and wind-pollinated (Gabriel and Garrett 1984). Pollen dispersal distance for insect-pollinated species may be low as insects may tend to visit proximal trees (Perry and Knowles 1991).

8.2 Tree/Stand Improvement Strategies

The effect of a silvicultural activity in the forest is influenced by the interaction of *genotype* and environment, which gives rise to observable or *phenotypic* variation. All characteristics of trees are controlled to varying degrees by heredity (e.g. apical dominance) and some traits can be modified by environmental manipulation (e.g. controlling the incidence of permanent stem forks by maintaining sufficient stand density to promote self-pruning).

Natural regeneration and stand manipulation in terms of phenotypic characteristics should be emphasized in the genetic management of the tolerant hardwoods. This concept differs from the genetic improvement program developed for Ontario conifers (OMNR 1987d). Although this approach provides a less effective means of using the genetic differences among trees, genetic manipulation of the existing forest can be effected in the natural regeneration of forests and in intermediate treatments such as thinning and improvement cuttings.

Harvesting desired species or phenotypes from stands while leaving only the undesired species and phenotypes results in changes in forest productivity and timber quality. “Selective” harvesting (high-grading), which is not to be confused with harvesting under the “selection system,” is rarely considered in genetic terms, but the potential negative impact on the genetic constitution of the forest stand can be tremendous (Maynard *et al.* 1987).

The two most serious forms of "dysgenic" activities (i.e. changes detrimental to the genetic quality of future generations) as applied to the tolerant hardwood forests of Ontario are:

- **Diameter-limit cuts**, which target the fastest-growing trees in a stand; those trees that have survived the process of natural selection have the potential to produce higher quality offspring (Wilusz and Giertych 1974)

- **High-grade harvesting** for selected species and phenotypes with specific characteristics; this practice changes species composition and leaves the poorest phenotypes to reproduce.

One or two generations of dysgenic selection will not result in future stands that are totally degraded genetically. In a naturally-regenerated stand, the poorer-growing, non-competitive, pest-susceptible genotypes will tend to be eliminated and the resulting stand can be of satisfactory quality. However, three or more generations of dysgenic selection can result in "minustype" stands (Zobel and Talbert 1984).

If a sufficient amount of acceptable growing stock remains to warrant further management under the selection system, the stand may be salvaged and can be made productive if proper regard is given to genetic principles and the silvical requirements of the residuals. These considerations can be made only during a well-planned and well-implemented tree-marking program during which the following desirable phenotypic characteristics are recognized (OMNR 1983):

- tree vigour, as indicated by external bark and crown appearance

- freedom from serious defects

- good form.

Genetic gains realized through management of the existing stand are less than those resulting from the planting of improved nursery stock, but these gains can be obtained quickly at minimum cost. The greatest gains from genetic management of a natural stand will be realized through the recovery in genetic quality of stands that have been subjected to high-grading in the past. Regeneration from seed, leaving the best-quality trees as seed producers, will provide the following benefits (Zobel and Talbert 1984):

- progeny that are well-adapted to the site

- improved tree form (which is usually highly heritable)

- increased or improved resistance to pests.

Gross total volume gains resulting from genetic improvement of the properly marked and harvested stand will likely be small since this characteristic is probably low in heritability (Kriebel and Gabriel 1969). Nevertheless, significant gains in net merchantable volume and quality will be realized through of the retention of the trees of highest potential and by reducing the cull factor in the stand.

8.2.1 Regeneration from sprouting species

Genetic improvement of any species will not occur when regeneration arises from sprouts of trees (e.g. red oak, white ash) that are already established, because the offspring are genetically identical to the parent tree (clones, in effect). Little can be done to improve the genetics of these stands beyond later crop-tree selection and thinning.

8.2.2 Thinning

Full expression of a tree's genetic potential is realized when the tree is growing in favourable conditions. An effective thinning program can control spacing and competition, providing better growing conditions for crop trees. In addition, thinning facilitates the selection of individual trees of greater potential for the residual stand.

Genetic improvement of the existing stand will depend totally on the tree-marker's ability to identify and rank the visible phenotypic characteristics of each tree being managed (Rudolf 1956; Clausen and Godman 1967; Boyce and Carpenter 1968; Sonderman and Brisbin 1978; Sonderman 1979). Criteria for phenotypic selection are as follows:

- **Quality-related characteristics**: straight stems, round boles with low taper, straight grain, good self-pruning, apical dominance, large branch angle and small branch diameter. Internal defect is often a function of history—a result of mechanical injury, for instance. Trees with such defects may be maintained in the residual stand if other characteristics are phenotypically superior to other individuals in the stand.

- **Growth-related characteristics**: tree height, stem diameter and growth rate, as well as volume, length, crown diameter and crown density.

Exceptions to the application of these criteria may be warranted in order to achieve other objectives, such as the maintenance of wildlife habitat (***see*** Section 10.0 "Habitat Management Considerations").

The tree-marker should also retain trees of non-commercial value when the tree is a healthy specimen of a species that is affected by a destructive pest. In stands where other trees are heavily affected, a healthy tree has probably been exposed to the pest and has greater potential for being a resistant specimen (e.g. butternut).

8.3 Artificial Regeneration

Seed sources of tree species are adapted to the environmental conditions of their place of origin. Genecology testing conducted at the Ontario Forest Research Institute has shown that some species are generalists (not finely-tuned to their environment of origin), whereas others, such as red oak, are specialists (very finely-tuned to their place of origin). Genecology testing has been completed for only five of Ontario's approximately 80 tree species. Until more species can be tested, a set of generic seed zones has been developed for application to all species. The seed zones are designed to minimize the risk of planting maladapted stock. In any artificial regeneration program, seed from the same seed zone as the planting location must be used.

In addition to using seed from the appropriate seed zone, there are several seed collection guidelines to ensure planting stock represents a wide genetic base:

- ensure seed is collected in good quality stands with healthy populations of the species being collected

- ensure seed is collected from a number of healthy, vigorous trees—not just one or two individuals

- seed collected in a good seed year usually will be of higher quality in terms of number of filled seed and germinative capacity.

8.3.1 Potential breeding strategy

In any future breeding program for one or more of the tolerant hardwood species, the principal objective is to obtain improved growth while preserving existing superiority over other individuals of the same species in terms of wood properties. In species with intermediate shade-tolerance, suppression-induced mortality tends to eliminate the less-efficient, slower-growing components of a stand. Kriebel (1963) notes, however, that there is a relatively low degree of selection pressure against slow-growing hard maple individuals, partly because of their shade-tolerance and elastic response to release. Breeding should concentrate on high-value products, especially lumber and veneer (Kriebel and Gabriel 1969; Cech 1971; Clausen 1973; Morgenstern 1979). In the future, it may be feasible to breed for features such as figured grains (e.g. curly, wavy, birdseye etc.) but this is impractical at present.

Generally, improvement of sawlog species concentrates on increasing the quality of individual trees rather than the gross volume, whereas improvement of fibre species is aimed mainly at increasing yields per hectare (Calvert 1979). Artificial regeneration with improved stock of mid-tolerant species may involve planting 125 to 250 potential crop trees per hectare, with the requisite site preparation and tending, to ensure optimal development. Costs per tree will be high and conversion costs per hectare will be moderate.

Before consideration is given to the initiation of a tree breeding program for any species the following aspects must be addressed:

- **level of planting program anticipated:** economies of scale dictate a planting program of millions before the investment in a tree improvement program will be economically feasible, unless the product has a very high value

- **level of genetic diversity of the characteristics of commercial importance:** the degree of genetic gain possible is dependent on the genetic variation of the characteristic of interest

- **ease of propagation** of planting stock

- **reproductive biology of the species**: species that begin reproduction at an older age usually require grafted seed orchards versus seedling seed orchards

- **long term investment** required to maintain a successful tree improvement program

- **suitability to plantation conditions** of the species

- **land base available** for plantation establishment.

In addition, Farmer (1973) suggests that a ranking of species that could warrant a breeding program investment should be based on the consideration of several factors, including:

- value increment rate

- predominance in the existing forest

- value for uses other than timber production

- ease of establishment

- area available for artificial regeneration

- likelihood and cost of breeding success

- cost of producing improved stock.

Seeding is the optimal means of effecting these artificial regeneration programs, with planting as a secondary means. Technology for regeneration of yellow birch through direct seeding is already in place. Similar technology for red oak and white ash has not yet been developed.

Vegetative propagation has been accomplished from stem cuttings for yellow birch (Hannah 1988b), black cherry (Farmer and Besemann 1974), hard maple (Gabriel *et al.* 1961; Morsink and Jorgensen 1974) and red oak (Isebrands and Crow 1985). Propagation by air-layering has been achieved for hard maple by Cunningham and Peterson (1965). These techniques could be useful in developing planting stock for any future genetically-improved clonal material.

8.3.2 Planting improved stock

Planting of improved stock must be done in the context of genetic management of the species on the landscape. It is critical that a balance be maintained between regeneration methods to ensure the maintenance of the genetic base of a species. Tree improvement strategies must include a plan for: 1) maintaining part of the regeneration effort as natural regeneration and 2) the use of seed collected in seed collection areas and seed production areas in addition to stock produced through orchards or vegetative propagation programs. As a general rule-of-thumb, the narrower the genetic base of the stock used, the lower the proportion of the land base that should be planted using the stock.

9.0 ECOLOGICAL FOUNDATIONS FOR SILVICULTURE

9.0 Ecological Foundations for Silviculture

by Brian Naylor and Fred Pinto

Wind, wildfire, and natural senescence appear to have been the principal factors creating canopy openings and consequently initiating regeneration in the tolerant hardwood forest prior to human intervention (Borman and Likens 1979; Runkle 1981; Canham and Loucks 1984; Whitney 1986; Frelich and Lorimer 1991). The effects of these agents were extremely variable. For example, catastrophic wind events (severe thunderstorm downdrafts, hurricanes, and tornadoes) flattened areas up to 1,000s of hectares in size (e.g. Canham and Loucks 1984). These blowdowns stimulated the establishment and growth of relatively even-aged stands that were comprised of a mixture of shade-tolerant, mid-tolerant, and intolerant hardwoods (e.g. ES 27). At the other extreme, minor wind events and natural senescence caused the death of individual trees or small groups of trees. Individual tree gaps encouraged the regeneration of shade-tolerant trees and the perpetuation of an uneven-aged forest comprised of tree species such as hard maple and beech (e.g. ES 25). Multi-tree gaps in the forest canopy encouraged regeneration of even-aged patches of species such as basswood and yellow birch and perpetuated uneven-aged forests of shade-tolerant and mid-tolerant hardwoods (e.g. ES 26).

Wildfire seems to have had an effect midway between these extremes. In the mesic tolerant hardwood forest, infrequent severe surface fires occurred following prolonged periods of drought (Heinselman 1981) and may have helped perpetuate mid-tolerant hardwoods such as yellow birch (Van Wagner 1993). Fire appears to have been a more prominent factor in xeric hardwood forest dominated by oaks. Frequent understory fires created appropriate seedbed conditions and controlled competing tolerant hardwood vegetation, facilitating the development of multi-aged oak stands (Van Wagner 1993; Guyette and Dey 1995).

The silvicultural practices applied in the tolerant hardwood forest tend to emulate some important aspects of natural disturbance processes and thus take advantage of the natural adaptations of the tree species comprising these associations (***see*** Section 9.2 "Silvicultural Systems"). For example, clearcutting produces relatively large forest openings with high light levels similar to the openings created by large catastrophic wind disturbances. Shelterwood cutting tends to emulate the light conditions produced by moderate intensity fires. Group selection and single-tree selection cutting tends to emulate the light conditions produced by multi-tree and single-tree gaps, respectively, that are created by minor wind events or natural tree senescence.

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 in the tolerant hardwood forest follows similar patterns (***see*** Section 9.3.4 "Silvicultural system modification by species" and Section 9.5 "Artificial Regeneration"). In shelterwood cuts, trees retained to provide seed have characteristics similar to those that would likely have survived a fire (large, thick-barked, high-crowned, vigorous, dominant and codominant trees). In selection cuts, trees retained are those that would be least likely to blow down (vigorous, low-risk individuals) and advanced regeneration is protected during felling and skidding (***see*** Section 11.0 "Harvesting Considerations").

Other silvicultural treatments may also be required to ensure that management activities emulate natural disturbance. For example, group selection harvest may create multi-tree canopy gaps that emulate those created by windthrow and thus produce light conditions that favour the establishment and growth of mid-tolerant hardwoods. However, windthrow uproots some trees, producing mounding, mixing humus and mineral soil, and creating a seedbed for species such as yellow birch. To emulate this effect, site preparation activities are occasionally required to supplement the ground disturbance created by skidding during logging operations (***see*** Section 9.4 "Site Preparation").

Natural disturbance such as fire removes much of the understory vegetation, creating conditions for the establishment and growth of fire-adapted tree species such as red oak. Silvicultural practices may attempt to emulate control of competing vegetation through use of prescribed fire, chemical or mechanical site preparation (***see*** Section 9.4 "Site Preparation").

The effects of forest management activities can differ in a variety of ways from those of natural disturbance. For example, heavy equipment used during harvest or site preparation activities may cause soil compaction, rutting, and erosion. While site impacts can never be entirely eliminated, operations must follow guidelines to minimize these effects (***see*** Section 11.0 "Harvesting Considerations"). Similarly, harvesting results in some loss of nutrients from a site when tree boles are removed. Forest managers may reduce the effects of nutrient losses by following the guidelines for downed woody debris (***see*** Section 10.0 "Habitat Management Considerations") and by carefully choosing harvest rotation ages and/or cutting cycles.

Traditional 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 will never have as many standing dead and declining trees as naturally disturbed forests, guidelines discussed in Section 10.0 are intended to ensure that the minimum requirements of cavity-users (and other wildlife with special habitat needs) will be met.

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/cutting cycle and the size, shape, and dispersion of operating blocks to emulate the mosaic of age classes, forest types, and landscape patterns created by natural disturbance.

9.1 Prescription Development

9.1 Prescription Development

by Al Corlett and Fred Pinto

Various policies and strategies commit forest managers to ensure:

- that forest practices emulate, within the bounds of silvicultural requirements, natural disturbances and landscape patterns (*Policy Framework for Sustainable Forests* [OMNR 1995])

- that forest operations prescriptions utilize, as the preferred option, silvicultural techniques that promote natural regeneration (e.g. *A Conservation Strategy for Old Growth Red and White Pine Forest Ecosystems for Ontario*, OMNR [1994]).

By developing an understanding of the natural life strategies of the plant species growing in the tolerant hardwood forest, with the intention of then emulating natural disturbance processes, a forest manager can design management approaches which recognize the biological limits and opportunities associated with each species group.

Resultant management approaches may incorporate a number of treatments to be implemented in a specific order. On Crown land in Ontario, forest managers are required to describe that series of treatments for each broad grouping of forest cover (i.e. forest unit) and ecosite (OMNR 1996a). 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 further required to prepare more specific forest operations prescriptions at the stand or operating block level. The following text describes how *silvicultural ground rules* and *forest operations prescriptions* can be developed.

9.1.1 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 method, logging method, renewal treatments, tending treatments and management standards for each forest unit and ecosite grouping (***see*** TABLE FMP-10 on page A-55 [OMNR 1996]).

Information contained in sections 2.0 to 8.0 can be used to obtain an understanding of the Great Lakes-St. Lawrence tolerant hardwood forest ecosites and the reproductive and growth adaptations of their constituent plant species. This information may be used by the manager to select appropriate ecosite groupings for the forest. A 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. For example, ES 24.2 and ES 26.2 have similar tree species, a similar range of soil depth, texture and moisture, high levels of hardwood regeneration and moderate numbers of herbs. They may, in general, be treated similarly if the objective is to manage for high quality tolerant hardwoods, while maintaining a component of mid-tolerants such as basswood, white ash or red oak in the stand.

Information found in sections 9.0 through 12.0 will be used to develop the silvicultural treatment package. These sections describe how stand and site conditions may be managed 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.

Forest managers should determine how well the possible silvicultural treatment packages may lead to the achievement of the objectives for the forest. For example, a manager should establish the emphasis which must be placed on the retention and renewal of certain tree species in order to meet forest biodiversity objectives.

The pattern of light selective harvests in the tolerant hardwood forests of the Great Lakes-St. Lawrence Forest Region in past decades, has provided a competitive advantage to shade-tolerant species such as sugar maple and beech, and has often not provided the necessary light requirements for mid-tolerant species such as red oak and yellow birch. The maintenance, and in some cases, restoration of mid-tolerants will require preferential retention of such species, and the deliberate modification of light levels to encourage regeneration and development of these species. These actions should be reflected in the silvicultural treatment regime for ecosites such as ES 23 and 29.

The consequences of a treatment package and the level to which it is applied should be evaluated using an appropriate and proven forest level simulation computer model (***see*** Section 7.0 “Stand Growth and Yield”). The results of the simulations will provide the managers and public an indication of how planned activities may affect the achievement of forest objectives and targets.

9.1.2 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 is a specific treatment package to be applied to an individual stand or group of stands (i.e. an operating block) which is selected from the appropriate *silvicultural ground rules* of the approved Forest Management Plan. Forest operations prescriptions must be certified by a Registered Professional Forester.

The stages of an intensive forest operations prescription are described in Pinto *et al*. (1996). Briefly, these stages involve:

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.

Field inspection

- confirmation of forest unit, ecosite, inventoried values and stand characteristics. The information required when implementing one of the partial cutting systems, includes species composition, stocking, structure and quality. (One suggested format for stand analysis is displayed in APPENDIX 9 of *A Tree Marking-Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993) although the format is periodically updated to suit local needs).

Development of site-specific targets

- Site specific targets are quantified descriptions of future 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*. 1996)

- To evaluate and develop stocking and structure targets for stands that will be managed using the shelterwood or selection silvicultural systems for tolerant hardwood stands (***see*** Anderson and Rice [1993]). Existing tree quality may be derived using information described in Section 5.3 "Assessing Individual Tree Quality Potential".

Prescription formulation and implementation

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

- update the 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 before conducting operations; for example, prescribed burning and the application of herbicides require additional planning, approval and documentation.

Monitoring and evaluation

- a forest operations prescription program provides information on the intent, rationale, site and stand characteristics, and treatments. Some of this information is required (***see*** Section C, Monitoring and Reporting *in*: Forest Management Planning Manual for Ontario's Crown Forests (OMNR 1996a)) in order to compare the expected and actual results. Information garnered from this process is used in the development of future silvicultural ground rules.

9.1.3 Stand Analysis

The objectives of management in the tolerant hardwood forest are diversified and include a range of potential silvicultural treatments. The system of stand analysis chosen to develop a forest operations prescription must therefore 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 stand analysis 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 tree quality, stocking, structure or species content
- with unreliable inventory
- where an error in judgement 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 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 prevent potential conflicts between forest users
- it reduces the potential of environmental degradation, such as rutting and erosion
- it minimizes the costs of harvesting, regeneration and maintenance, and provides opportunities to verify progress in meeting site and forest objectives
- it provides the best opportunity to verify the accuracy of the FRI and subsequent prescriptions

- it allows for better scheduling of operations, permitting the mitigation of site damage often while increasing productivity

- it allows operations to be budgeted more accurately and provides for determination, in advance, of stands and blocks which are not feasible to operate.

The assessment of stand conditions leading to prescription development may include:

Confirmation of species

- species content and balance provides the first indication of the range of appropriate silvicultural systems. Options are developed based on shade- tolerance and with consideration to the natural regeneration strategies.

Stand stocking

- indicates the stage of treatment required, or the timing of the next required stand intervention (***see*** Section 6.1 “Stand Stocking”).

Stand structure

- indicates the degree of growing space utilization by size class, and thus growth rate maximization. Structural information is used in the clarification of tree marking direction, for instance in the setting of targets related to optimal residual stand condition (***see*** Section 6.2 “Stand Structure”).

Individual tree quality

- indicates the value and volume growth potential of stems which may be retained as residuals, thus indicating the viability of a system such as Selection (***see*** Section 5.3 “Assessing Individual Tree Quality Potential”).

Soil texture and moisture regime

- if ecosite has been determined, the range of moisture regime classes will be available. More accurate assessment of moisture regime, combined with soil texture analysis will allow better definition of productivity for both desired and competitive regeneration, and thus indicate future investment requirements related to site preparation, tending and/or artificial regeneration. Some interpretation of potential site damage from logging or silvicultural activities may also be derived from this information.

Ecosite classification

- suggests target species composition
- indicates species suitability and growth potential.

Critical ecological features

- will often be considered and accommodated during the tree-marking operation, and must either be noted in the pre-harvest assessment, or as is often the case, during the actual tree marking process. Some stand analysis will thus be completed by well-trained tree-markers, ensuring that stick nests, scattered conifer patches in hardwood dominated sites, cavity trees, *etc*. are noted.

Role of site and ecosite in decision making:

Ecosite classification will allow identification of long-term potential to achieve certain forest management objectives, and is thus an important component of the silvicultural ground rules. Poor stand development and performance may be a reflection of unsuitable site conditions, which will impose limitations on potential value growth and justifiable investment level. The understanding of a given ecosite with its characteristic mixture of species should provide the manager with the tools to consider which silvicultural practices best emulate natural processes on that site. Decisions related to desired end-products should logically follow.

The frequently encountered variable stocking, structure and quality characteristic of many Great Lakes-St. Lawrence forests may however be a function of historical events (such as high-grading, natural catastrophe, or even lack of disturbance), rather than limitations of site or biological potential. The forest manager must consider whether such stands have the qualities required to support intensive investments by examining ecosite in conjunction with other features of the stand.

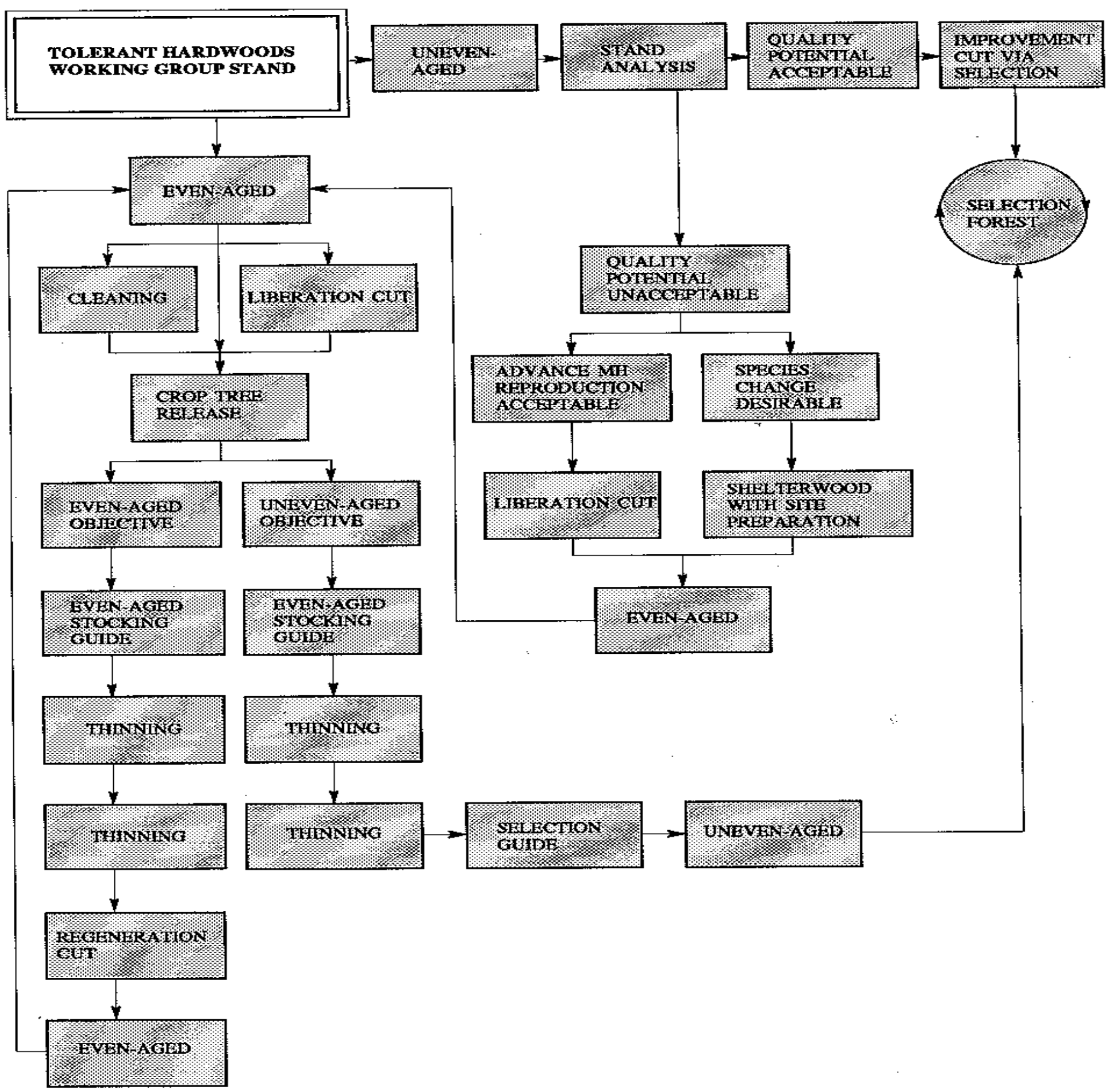
9.1.4 Prescription Setting

This section can deal only with general guidelines because hardwood stands are so variable, and prescriptions will vary with the unique combinations of factors described previously. An overall decision pathway is provided in FIGURE 9.1.1 which outlines some of the fundamental management routes available in treating the tolerant hardwood forest, the details of which will be described in Section 9.3 “Implementation of the Silvicultural Systems”, Section 9.4 “Site Preparation” and Section 9.6 “Stand Maintenance”.

Of more practical use, a treatment key is presented in TABLE 9.1.1, which provides a sequential, discriminant pathway leading to an initial approximation of an appropriate stand prescription. The branch-point decisions in the key that involve stand quality potential use the results of the stand analysis procedures referred to in Section 9.1.3 “Stand analysis”.

Other sources of prescription keys are found in the published literature for species in the tolerant hardwood forest, such as Leak *et al*. (1987, 1969) for northern hardwoods in the northeastern United States; Marquis *et al*. (1984) for Allegheny hardwoods; Trimble et al. (1974) for Appalachian forest stands; Roach and Gingrich (1968) for upland central hardwoods; Sander (1977) for oaks in the north central United States; Arend and Scholz (1969) for oaks in the Lake States; Tubbs (1977b) for northern hardwoods in the Lake States; and Brand (1981) for oak and northern hardwoods in the Lake States.

FIGURE 9.1.1: Decision pathways for prescribing silvicultural treatments in tolerant hardwood stands



In Ontario, a treatment key has been written by Irwin (1988) for ANSI (Areas of Natural and Scientific Interest) applications in southern Ontario hardwoods. A tolerant hardwood key given in *Management of Tolerant Hardwoods in Algonquin Provincial Park* (OMNR 1983) was adapted for general use in the former Algonquin Region. An enhanced version of this key is presented in Anderson and Rice (1993).

This key applies only to the production forest and to sites considered adequate for quality growth of the principal species of the tolerant hardwood forest. The range of sites found in each of the three major ecological sectors is outlined in Section 3.0 "Site". Ecosystem management goals may require alterations of prescribed silvicultural treatments in some cases to meet specific and/or local needs. In following the modified route, however, it should be realized that timber production targets may not be fully achieved. All references to silvicultural systems must be considered with respect to established guidelines, ground rules, and policies.

Suggested "silvicultural options" for each of the ecosites on which the management of the tolerant hardwoods may be considered are included in APPENDIX F. These option tables will provide an indication of the treatment approaches that are ecologically appropriate, and capable of achieving various forest management objectives as long as consideration is provided to the limiting factors that are indicated. This information is intended for use at the planning level, and would ideally be confirmed through on-site inspection and comparison to the guidance provided in Table 9.1.1 before commencement of operations.

TABLE 9.1.1: Recommended treatment key for species of the tolerant hardwood forest

STAND DESCRIPTION	RECOMMENDED TREATMENT
Overstory (DBH 10 cm+) < 4 m^2/ha	
• acceptably stocked to desirable regeneration (as determined by the management plan and ecosite type).	• Do nothing. Review when stand reaches polewood stage *or* do a final removal cut if desired (Section 9.3.2)
• inadequate stocking to desirable regeneration	
• if tolerant hardwood regeneration desired	• Do nothing. (May take 10 years to obtain adequate stocking of Mh; Be unlikely to establish).
• where mid-tolerant hardwood regeneration is desired (for example By on ES 29, or Bd on ES 26).	• **See**: Section 9.3.4. **Note**: competition control, site preparation during a seed year and follow-up tending will likely be required.
• if conversion to a conifer species is desired (for example, Pw on Ecosites 23, 24 and 27).	• **See**: *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*
Overstory >= 4 m^2/ha	
• polewood component >= 75% of total Basal Area (BA)	
• with no potential for future quality development (< 9 m^2/ha AGS).	• Do nothing. Removal cut(s) of the overstory under Shelterwood (Section 9.3.2) with no crop tree release in the poles is an option if desired or delaying this harvest until polewood component reaches a merchantable size, however, assume limited quality production.
• with potential for future development	• Crop tree release in the poles (Section 6.1 "Stand Stocking" and Section 9.6.1. "Tending") with cutting in the sawlog size class as required.

Sawlogs > 25% of total BA or stand has uneven-aged structure	
• limited potential for quality development (< 9 m^2/ha AGS)	
• stand dominated by Mh or Be, and	
• AGS material concentrated in Poles-Small Sawlog sizes or if Sawlog AGS is >= 7 m^2/ha	• Manage under Selection (Section 9.3.1).
• AGS material not concentrated in Poles-Small Sawlog sizes and Sawlog AGS is < 7 m^2/ha	• Manage under Shelterwood (Section 9.3.2). Selection (Section 9.3.1) is an option if a significant component of Be is desired and for areas where Shelterwood is not consistent with other management objectives.
• significant component of mid-tolerant hardwoods present (Or, Cb, By, Aw, Bd)	
• understocked to mid-tolerant regeneration	• Regenerate mid-tolerants under either Group Selection (Section 9.3.1.2) or Shelterwood (Section 9.3.2).
• acceptable stocking of mid-tolerant regeneration	• Release regeneration through either Group Selection (Section 9.3.1.2) or a Shelterwood removal cut (Section 9.3.2).
• stand has a significant He component	• Manage He areas under Shelterwood or Group Selection (see Section 9.3.4) and ***see***: *Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*.
• stand is dominated by Intolerant Hardwoods (normally ES 27)	
• tolerant hardwood regeneration desired	• Manage under Shelterwood (Section 9.3.2).
• conversion to white pine	• ***See***: *Silvicultural Guide for the Great Lakes- St. Lawrence Conifer Forest in Ontario*.
• mix of tolerant and intolerant hardwood regeneration is desired	• Clearcut.
• Potential for quality development (>= 9 m^2/ha AGS)	
• Stand dominated by Mh or Be where tolerant hardwood regeneration is desired	• Manage under Selection (Section 9.3.1)
• Stand has a significant component of mid-tolerant hardwoods	
• tolerant hardwood regeneration with a component of mid-tolerants is the desired result	• Manage under Selection with Group Selection openings (Section 9.3.1.2) modified for specific target species (Section 9.3.4)
• a significant component of mid-tolerant regeneration is desired	• Manage under Group Selection (Section 9.3.1.2) or Shelterwood (Section 9.3.2) with modifications for desired species (Section 9.3.4).
• stand has a significant component of hemlock	• Manage hemlock areas under Shelterwood or Group Selection (Section 9.3.4) and **see**: *Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*.

9.1.5 Tree Marking

Tree marking is the mechanism for regulating forest management activities and implementing forest operations prescriptions that involve partial cutting. An example of a partial cutting silvicultural system is *single-tree selection*. In this system, trees are marked for removal. Conversely, within the *uniform shelterwood* system, for both crop-tree release and thinning procedures, it is often the case that residual trees—those which are to remain uncut—are marked.

It is important that the prescription indicates what the management objectives are in terms of the silvicultural system to be employed, the quality of products considered, the implementation of measures concerned with non-timber values and the long-term goals for the designated area. Armed with this information, a well-trained tree marker is expected to adapt the prescribed management approach, in a biologically-appropriate manner, often while encountering unforeseen forest conditions. Thus, the continuity of stand level objectives, and ultimately forest level objectives, are ensured.

Marking is often a compromise between maximizing present harvest volumes and value, and optimizing future forest growth and quality timber production. At the same time, marking must provide suitable conditions for regeneration and for the maintenance of other forest values. The nature of the compromise often causes variation in the "on-the-ground" application of tree marking from one location to another (McLean 1976).

The effort put into stand diagnosis and prescription setting is wasted if tree marking objectives cannot be effectively applied in the field. Sometimes a structural goal cannot be met because of local stand conditions. This is acceptable; good silviculture is more important than strict adherence to a structural guide. However, marking should not be undertaken without a structural guide, regardless of the partial cutting system prescribed (Leak and Filip 1975).

Marking quality must not be sacrificed to reduce costs. Poor-quality marking wastes money and can reduce the future development of forest values. Considering the silvicultural importance of the procedure and the potential value of well-managed forest products, marking costs are a modest and justifiable expenditure (Trimble and Wendel 1963).

Details concerning the implementation of tree-marking procedures for single-tree, group selection and uniform shelterwood silvicultural systems are outlined in *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

9.2 Silvicultural Systems

9.2 Silvicultural Systems

by Al Corlett, Brian Batchelor, Harvey Anderson, Carl Corbett, Scott Reid and Dave Deugo

A silvicultural system is a planned program of silvicultural treatments carried out during the entire "life" of a stand for the purpose of controlling the establishment, composition, and growth of the forest. The nature and intensity of application of its components (harvesting, regeneration, and tending) varies with accessibility, markets, the quality of the existing forest and its growth potential, site quality, and management objectives.

The choice of an even- or uneven-aged method is based primarily on the silvics of the species of interest as discussed previously, but also on the current condition of the stand as affected by past management or natural influences, the stands' potential as indicated by ecosite, and the management objectives for the forest. Managers should endeavor, as a principle, to select the silvicultural system which most closely emulates natural process and produces a stand with a "natural" composition and structure.

Only shade-tolerant species (such as sugar maple, beech or perhaps white ash) may be managed under either method. Species with less shade tolerance (yellow birch, black cherry, red oak) are most efficiently regenerated and managed under even-aged methods, or a modification of the uneven-aged system which allows for representation of small even-aged patches within the stand.

The silvicultural systems that fall under each method are briefly described below.

UNEVEN-AGED METHOD

- **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. Regeneration is generally natural (OMNR 1996a).

EVEN-AGED METHODS

- **Shelterwood system**

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

- **Clearcut system**

  A silvicultural system for 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 1996a).

Any of these systems will allow for a variety of modifications (e.g. strip-cut, patch-cut) 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. The variation may occur in terms of appropriate modifications to the systems, or in terms of the degree of application or follow-up. Product values, management objectives, market availability, 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 these 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 will contribute greatly to the successful application of these methods. The complexity of some of these intensive activities requires a correspondingly intensive level of training of technicians and forest workers and an adequate funding base. This is especially important in terms of site evaluation and application of tree - marking technology. These factors are dealt with in detail in a companion manual: A *Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

9.2.1 Selection system

In practical terms, the selection system is a periodic partial cutting, controlled by basal area, using vigour and risk characteristics to determine individual tree selection. 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 high-quality products through a representation of all diameter classes (ultimately of all age classes) distributed throughout the stand.

The selection system should not be confused with the loosely used terms “selective cutting” or “diameter-limit cutting”, which in most cases are used to mask a process of high-grading. Such techniques negatively affect the genetic base by leaving the poorer trees as seed sources.

Evaluations have been published for the selection system by Nyland (1987) and Marquis (1975), and for group selection by Leak and Filip (1977) and Roach (1974).

The selection system can maximize the production of high-quality tolerant hardwood forest products with a minimum of aesthetic and environmental impacts, provided certain criteria are met. It can best be implemented on accessible, highly productive sites containing a major representation of shade-tolerant species (mainly sugar maple), having the capacity to respond to release at relatively advanced ages.

Preferable sites are fresh to moist (depending on species), developed on relatively deep, well drained silty sands or sandy loams, often associated with morainic mid-slopes and drumlinoid landforms.

A basic level of management using selection system principles can be applied to "less-than-best" sites if reasonable structure and quality exist, although value growth, cutting cycle, and time-to-maturity will be affected adversely.

Features of the system:

- emulates stand composition and structure created by gap-phase processes associated with minor wind events and normal tree decadence

- system is well suited to the management of shade tolerant species

- continual overstory represents a permanent seed source

- growing space is occupied continuously, protecting the land and stabilizing the environment

- there is permanent vertical closure of the stand (i.e. stand is more windfirm); there is a continuous flow of forest products of potential high quality

- cover is maintained, as is a food supply for many species of wildlife which are adapted to a forest maintained by gap phase processes.

Challenges related to the implementation of the system:

- high crown closure levels will discourage mid-tolerant 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 low-quality material in early cuts; market conditions may preclude removal of all designated low-quality material in harvest cuts

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

Variations of the system include:

Uniform selection (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 shade-tolerant species (i.e. sugar maple, beech, hemlock).

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 of intermediate shade tolerance (i.e. yellow birch, red oak, white ash, and occasionally black cherry), which additionally may require both cutting of smaller residuals to create a patch, and also site preparation. 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.

GROWING CONDITIONS CREATED

Application of the selection system provides many of the environmental conditions required by species whose natural strategy is that of gap phase replacement, so it will largely limit plant diversity to shade-tolerant species.

Normal application of the selection system usually results in a variable degree of canopy opening throughout the stand, some of which will emulate the effect of group selection for species that do not require site preparation to regenerate (e.g. sugar maple, white ash).

9.2.2 Shelterwood system

The shelterwood system of reproduction involves gradual removal of the entire stand in a series of partial cuttings that extend over a fraction (20+ per cent) of the rotation. The degree of residual crown closure, and the residual species composition of the overstory may be modified to encourage or discourage the 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 or to shift species composition to a more desirable condition.

Features of the system:

- emulates stand structure created by moderate intensity understory burns

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

- residual overstory ameliorates climatic extremes, thus reducing desiccation of the seedbed and losses of succulent seedlings from heat injury

- aesthetic quality is maintained

- adjustment of light conditions by modifying overstory levels can be used to favour species that are moderately shade-tolerant, while suppressing development of competing vegetation, especially shade-intolerant species

- silvicultural costs are lower as a result of reduced tending requirements and the greater likelihood of natural regeneration.

Challenges related to the implementation of the system:

- more technical skill is required (in terms of layout and implementation of the tree marking activity) 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 residuals

- immediate logging costs are higher than for clearcutting.

Components of the system:

The Shelterwood system normally involves a minimum of two cuts to establish the regeneration and then to release this regeneration through the removal of the remaining overstory. There are three distinct stages of cutting employed in the Shelterwood system:

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

- Seeding 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(s): residual stand is removed in one or two operations, to release well-established regeneration.

Cuttings may vary in configuration and number although consideration has to be given to the above stages in any modifications of the Shelterwood system.

Variations of the system:

Uniform shelterwood

Canopy is (periodically) opened uniformly throughout the entire stand. This method is most applicable in instances where site or seedbed protection is essential, and aesthetics are a consideration. Crown closure targets are used to control residual tree distribution.

Strip shelterwood

The stand is cut in strips that are advanced gradually across the area. At any given time cutting is concentrated in certain strips and the rest of the stand remains temporarily untouched.

The normal method of applying this system is to start on one side of the stand and conduct a seeding cut on the first strip. After a few years a removal cutting is made on the first strip, and the next strip is given a seeding cutting. A few years later the first strip is subjected to a final cutting, the second strip to a removal cutting, and a third strip to a seeding cut. In this way the series of cuttings progresses strip by strip across the stand (Smith 1986).

The strip shelterwood method can also be applied in another variation that involves clearcutting in very narrow strips (no wider than half the height of the stand, [Smith 1986]) so that the side shade of the trees on the adjacent strip of uncut timber provides the necessary protection.

GROWING CONDITIONS CREATED

When applied properly, the shelterwood system will provide an environment of partial shade from a high, well 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 mid-tolerant hardwoods were naturally adapted. It is therefore a viable management option for stands with a significant component of mid-tolerants where regeneration of these species is a primary objective.

Shelterwood is one viable option for the management of light-seeded, shade tolerant species such as hemlock, although higher crown closure levels are required to provide hemlock with some protection from competing tolerant hardwoods.

9.2.3 Clearcut system

Clearcutting removes the overstory in a single operation, laying bare the area treated, leading to the establishment of an even-aged forest. Maximum cutover size is critical if natural regeneration from seed is sought; attention must be paid to normal seed dispersal distances of the target species.

Features of the system:

- system is well suited to the management of shade-intolerant species adapted to take advantage of major disturbances; harvesting operations are made more efficient with immediate availability of higher volumes per unit area
- emulates patches of early successional forest created by catastrophic wind events or fire (***see*** Section 10.0 “Habitat Management Considerations” for a detailed discussion)
- no residual trees are left that could deteriorate, although significant loss of advance growth may occur
- most silvicultural input and investment follows the harvest
- simple regulation of cut by area.

Challenges related to the implementation of the system:

- possible reduction in genetic diversity unless regeneration is established prior to the harvest
- competition from intolerant species is intense
- entire stand is exposed at one time
- 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 system include:

Seed-tree

Normally 10 to 35 trees of seed-bearing age per hectare are retained to provide the seed supply required over the regeneration period. Although there are visual similarities to shelterwood treatments, insufficient crown cover is left following a clearcut with seed trees to have either the purpose or the effect of providing a significant amount of shade. The system has sometimes been considered “a half-hearted gesture toward regenerating forests during the early stages of deliberate forest management” (Smith 1986). Managers must be aware that treatment failures usually result from the inadequate number and fecundity of seed trees, or the failure to invest in required site preparation following the harvest, and modify their operations accordingly. The varied habitat provided by the residuals creates more structural diversity than that found in unmodified clearcuts. This modification of the clearcut system simulates in many ways the survival of scattered trees remaining after natural disturbance.

Patch clearcut

The physical dimensions 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, configuration, placement and association with other approaches. When direct seeding or planting is anticipated, seed source is not required and patch size is less critical but should conform to local land-use strategies. With their sometimes highly irregular boundaries, patch clearcuts provide more edge-effect than rectangular cuts (e.g. strips, blocks), and hence are of greater value to some wildlife species.

Progressive strip

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.

GROWING CONDITIONS CREATED

Application of the clearcut system provides light conditions typical of those following a severe burn or wind storm. 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 system is therefore most suited to the management of shade-intolerant species such as poplar or white birch. As a result, in Ontario, application of any of the basic clearcut systems is extremely limited in the Tolerant Hardwood Forest. In some cases the low-quality overstory may be removed completely in a single removal cut; however, in such cases, advanced regeneration must be present. The system is then better defined as a “one-cut shelterwood” (***see*** Section 9.2.2 “Shelterwood system”).

An overall perspective on using clear cutting in even-aged forest practice is given by Nyland (1972).

9.3 Implementation of the Silvicultural Systems

9.3 Implementation of the Silvicultural Systems

by Al Corlett, Brian Batchelor, Carl Corbett, Scott Reid, Dave Deugo and Harvey Anderson

Forest managers seldom deal with pure stands and normally must accommodate the silvical needs of more than one desired species within a stand. This section deals with associations of species and a variety of stand objectives. Sugar maple and beech are normal associates, but quite commonly will occur with varying quantities of red oak, white ash, black cherry, basswood or yellow birch. Hemlock may occur as scattered individuals in a sugar maple stand, or as concentrations in localized areas of varying size within a maple stand. Where management approaches are intensive, continual modifications to, or combinations of the systems within a given stand will ensure that long-term forest objectives are met.

All of the seven principal species in the tolerant hardwood forest can be regenerated naturally using appropriate silvicultural treatments, some more easily than others. Most can be established artificially by direct seeding or planting, although this is usually the choice only where a seed source is lacking or where conditions are unfavourable for natural regeneration to occur. Success will be fully achieved only when the chosen procedure creates the proper microsite conditions for the target species (Blum 1975).

The choice of silvicultural system is based on:

- an understanding of the silvical requirements of the desired species mix
- the current condition of the stand as affected by past management or natural influences
- the potential of the stand as indicated by ecosite
- the management objectives for the forest.

This section includes general guidance related to the implementation of the major silvicultural systems. This is followed by an outline of the critical silvical features of the various species and resultant species-specific treatment modifications required. General overviews of natural regeneration methods for these species are given by Crow and Metzger (1987), Bjorkbom and Walters (1986), Nyland and Marquis (1978), Tubbs *et al.* (1983) and Arend and Scholz (1969), Anderson *et al.* (1997 *in press*). Further discussion related to artificial regeneration approaches for species in the tolerant hardwood forest is detailed in Section 9.5 "Artificial Regeneration."

9.3.1 Selection system

9.3.1.1 Single-tree selection

STAND CRITERIA

Stands qualifying for selection management generally have a minimum of 9 m^2/ha in trees 9 cm DBH and larger (or 7 m^2/ha in trees 24 cm DBH and larger) of crop quality (AGS). Stands with less than this can be managed under the selection system, however, it will take longer to realize the expected improvements in volume and value production.

Decisions critical to successful application of the system involve choice of cutting cycle length, maximum residual diameter, target stocking, structural configuration or Q-value and species composition requirement (i.e. inclusion of moderately shade-tolerant species). Details of stand parameter development are discussed in Section 6.0 “Stand Stocking and Structure” while quality criteria and marking guidelines are outlined in Section 5.0 “Quality Development in Trees” and in *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993). Qualifying stands should have the potential of developing recommended stocking and structure within 40 years.

SYSTEM IMPLEMENTATION

Ideal stocking targets vary depending on site potential and cutting cycle. An ideal residual stocking target of 20 m^2/ha with a 20-year cutting cycle is applied throughout much of the southern and central portions of the Great Lakes-St. Lawrence Forest Region. In the Deciduous Forest Region, a 15 year cutting cycle is often applied, with a 20 m^2/ha stocking target, but structural targets are adjusted accordingly. A provisional stocking target of 18 m^2/ha with a 20 year cutting cycle is recommended for the Algoma/North Shore area (Rice *et al.* 1997 *in press).* See Section 6.0 “Stand Stocking and Structure” for recommended residual stocking levels by size class (TABLE 6.2.1).

Actual targets for individual stands vary depending upon species composition, stand structure and quality distribution (***see*** Section 4.0 “Silvicultural Prescription Development” in *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* [Anderson and Rice 1993]). As a guideline, researchers recommend that at a maximum, an average of 1/3 of the total basal area within a stand can be removed in one cutting operation (Leak *et al.* (1969), Marquis *et al.* (1992) and Nyland (1987)). They caution that heavier cutting may reduce volume production in subsequent cutting cycles.

Initial stand entries into forests previously managed in an unregulated fashion normally must focus on stand improvement. Stocking targets are addressed while removing much of the poor-quality material. Future cuts continue this process and also serve as conditioning cuts. In the process, stand structure and quality are improved.

The best-quality trees are retained as "residual capital" in order for them to grow and increase in value. The major goal of the selection system is to concentrate or transfer growth to the best quality trees in the stand by releasing them from competing trees. Forest operations must maximize the number of residuals and regeneration that are free from damage (***see*** Section 11.0 "Harvesting Considerations") or the objective of achieving increased high quality production will be delayed.

9.3.1.2 Group selection

STAND CRITERIA

There are two main reasons for applying group selection in the tolerant hardwood forest:

- to provide sufficient light for mid-tolerant species such as white ash, yellow birch, basswood, red oak and even black cherry to regenerate and develop in stands where they would normally be lost to suppression in the light-deficient understory

- as a tool to promote quicker conversion of even-aged stands to an all-aged condition.

Decisions critical to successful application of the system include size, shape and location of openings, cutting cycle length, and the method of regulating the periodic harvests.

SYSTEM IMPLEMENTATION

In Ontario, group selection principles have been applied more as a modification of the single tree selection system, than through the stand level implementation of the group selection system. Openings are created when opportunities arise to regenerate mid-tolerant species in stands dominated by tolerant species – often where the tree marker encounters a combination of favourable site conditions, the availability of a suitable seed source, and the presence of groups of lower quality, large diameter individuals which can be removed without impacting on sustainability of the site.

As an example, stands that are predominantly ES 26.2 (maple/basswood) may have ridges typed as ES 23.1 (red oak/hardwood) and cove sites typed as ES 29.2 (sugar maple/yellow birch). An intensive management approach will recognize this variation in site potential. Openings can then be created in locations within the stand that have a higher potential for regenerating the mid-tolerants (e.g. hill tops for red oak, fresh mid-slopes for basswood, or lower moist areas for yellow birch). The resultant condition is a mosaic of even-aged patches of mid-tolerant species within a forest otherwise dominated by uneven-aged tolerant hardwoods.

The application of the group selection system as the main system for regeneration across entire stands is new to Ontario but holds promise in areas:

- more heavily dominated by mid-tolerant species

- where it is more practical to deal with regeneration in manageable small openings

- where the open appearance or biological effect of heavy or total canopy removals associated with the shelterwood system is unacceptable

- when trying to accelerate the conversion from even-age to uneven-age conditions.

Group size, distribution and location is determined on a site specific basis. Groups normally range between 0.02 ha and 0.20 ha (circular patches 16 m to 50 m in diameter or 1 to 2 times the canopy height [Leak and Filip 1977; Miller *et al.* 1995]), depending on the light requirements of the target species. Larger openings tend to support greater proportions of intolerant species, fewer tolerants and more competition from shrubs and herbaceous species (Dale *et al.* 1995). Some adjustment of opening size may be required to compensate for the effect of aspect and topography on available light.

Group openings should be placed within the stand using a “worst first” approach – where potential growth or value returns are low compared to other parts of the stand. Such locations include groups of mature trees, undesirable species, or poor quality trees that exhibit relatively low potential growth or financial returns (Miller *et al.* 1998).

Success is greatly enhanced if desired advanced regeneration is established prior to the creation of the group openings, especially for difficult to regenerate species such as red oak. However, non-target species with diameters of 2 cm DBH or greater which have been suppressed or will not contribute to long term stand level objectives will interfere with the development of desired regeneration, and should be removed from group selection openings (Miller *et al.* 1995). Follow-up maintenance to ensure adequate stocking and the provision of competitive advantage to the species being managed is critical to the attainment of long-term goals.

Thinning or improvement cutting between groups is dependent on overall stand management objectives. Partial harvest cuts to remove individual trees with infectious diseases will improve returns and reduce overall stand health problems (OMNR 1998), however they will also encourage tolerant hardwood regeneration which may increase competition problems during later operations aimed at increasing the component of mid-tolerant species. In most cases, thinning between group openings is desirable to improve overall stand quality provided operations remain economically viable and contribute to the attainment of long-term goals.

Management under the group selection system can be regulated by area or volume. In general, the total volume from the combination of selection thinning and group selection openings should not exceed the periodic stand growth (Miller, et. al. 1995). As a rule the area in group openings should not exceed the total area of the stand over a single rotation. If operating with a 100 year rotation and a 20 year cutting cycle, a maximum of 20 % of the stand area should be in group openings each cutting cycle (Leak, W.B. pers. com. 1996), assuming there is no thinning between openings. Thinning between openings will proportionately reduce this percentage.

The inclusion of group selection openings will require the retention of higher stocking in the areas between groups in order to maintain the target overall residual basal area. For example, a stand having a pre-harvest basal area of 26 m^2/ha, a targeted post-harvest basal area of 20 m^2/ha, and a prescribed 10 per cent of its' area to be in openings, would require the retention of approximately 22 m^2/ha in the areas between group openings. Stands that develop under this combination of group selection and single-tree selection will be uneven-aged and have a reverse "J" shaped frequency distribution.

9.3.2 Shelterwood system

The shelterwood system is the method of choice where regeneration to mid-tolerant species is a primary objective. It is recommended for sugar maple if growth and quality of the stand are inferior because of site limitations (e.g. dry moisture regime; shallow soil; imperfectly drained soil; heavy-textured soil) or on productive sites where the overstory does not meet the quality criteria for selection. Beech generally does not regenerate well in stands where the crown closure is reduced significantly by shelterwood or clearcutting.

Decisions related to the stage of the shelterwood system applied, or the exact procedure for implementation, are dependent upon species composition of the stand, stand structure and species mix desired.

Normally the procurement of regeneration through the seeding cut of the shelterwood system is the first objective in unregulated hardwood stands. One or more removal cuts are then carried out as required.

Tree-marking for shelterwood is based on per cent residual crown cover and not on basal area. Basal area is not a good indicator of canopy closure from species to species in stands with a range of diameters. For this purpose, crown area tables developed by Godman and Tubbs (1973) for the Lake States or by Leak and Tubbs (1983) for the northeastern United States may be used. Similarly, even-aged stocking guides may be used to indicate crown closure. Refer to Section 7.0 "Stand Growth and Yield" for information on stocking guides and their use. A relationship between basal area and canopy closure is shown in APPENDIX 8(d) of *A Tree-Marking Guide for the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993).

PREPARATORY CUT

The preparatory cut is designed to improve and develop the crowns of thrifty seed-bearers of the desired species. This is done by targeting for removal, undesirable species and individuals competing with the potential seed trees. This treatment is normally scheduled when the stand is in the 61-80 year age class. At this stage of development, the stand is capable of significant further diameter growth, therefore regeneration is not yet an objective. Cutting intensity can be determined using the even-aged stocking guides shown in Section 6.0 "Stand Stocking and Structure."

SEEDING CUT

A seeding cut is done when new regeneration is required. Thinning must take place from below and concentrate on removing the most defective and least vigorous trees, leaving better-quality trees for seed, site protection and high-quality wood production. Actual crown closure targets will vary depending upon the light requirements of the desired species. Follow-up treatments may be required depending upon the regeneration requirements of the species in question (***see*** Section 9.3.4 “Silvicultural system modification by species”).

REMOVAL CUT

Removal cuts are implemented when the regeneration is well established. The determination of whether or not regeneration is well established and if the removal cut should be carried out in one or more operations depends upon the target species being managed (***see*** Section 9.3.4 “Silvicultural system modification by species”).

A final removal cut may aesthetically resemble a clearcut, however, biologically the two are different since the final shelterwood removal cut is intended to release established regeneration whereas regeneration is secured after the clearcut harvesting operation.

When applied to stands that contain some high-quality polewood (especially in groups) or individual small sawlogs, retention of part of this acceptable growing stock as residuals or “standards,” to provide (with little investment) a later, intermediate harvest and to meet aesthetic, habitat, or ecological objectives may be justified as an option. However, such residuals may suffer from excessive exposure resulting in crown die-back, epicormic branching and in some cases, mortality.

9.3.3 Clearcut system

Clearcutting to develop new even-aged stands from seed is the least suitable method for timber management of most species in the tolerant hardwood forest and its’ application is limited in tolerant hardwood management in Ontario. In some cases, the low-quality overstory may be removed completely in a single “liberation” cut if advanced regeneration is present. In such cases the system is better defined as a final removal cut, i.e. a one-cut shelterwood (***see*** Section 9.2.2 “Shelterwood system”). As in any removal cut standards may be left to meet aesthetic, habitat, or ecological objectives without affecting the development of the new stand.

When advance growth is present, or when direct seeding or planting is anticipated, a seed source is not required and patch size is less critical. Too large a patch may increase pioneer species competition, but in any case patch design should conform to local land-use strategies.

Clearcuts may be appropriate when converting to species other than tolerant hardwoods (***see*** Section 9.5.3 “Conversion to/from the tolerant hardwood working group”).

9.3.4 Silvicultural system modification by species

SUGAR MAPLE

A shade-tolerant, heavy-seeded species, sugar maple can reproduce and thrive without seedbed preparation under partial-cutting systems such as single-tree selection or group selection and readily regenerates as an even-aged stand in shelterwood cuttings (Tubbs 1977a). It will dominate in clearcuts if well-established (about 1 metre tall) advance growth is present before cutting. It does not regenerate well from seed after clearcutting, or compete effectively in severe openings associated with block or strip clearcuts except where the area is rapidly invaded by short-lived raspberry or brush species, which may tend to inhibit the growth of intolerant tree species. Sugar maple may regenerate under dense raspberry cover but may require ten years to become fully stocked and free-to-grow. In some cases, strong stump sprouting from smaller stems may dominate parts of clearcuts.

Recommended regeneration procedures are determined largely by site and overstory quality. If the stand overstory is uneven-aged, of good quality and growing on fresh silty sands or sandy loams, single-tree selection is the system of choice. Stocking and stand structure are managed to promote quality growth and yield in the overstory, while ensuring recruitment of the developing regeneration into growing stock at each cutting cycle (***see*** Section 6.0 “Stand Stocking and Structure”). Height growth of regeneration will vary with overstory stocking level but should be about 30 cm per year.

If the current stand is overmature or of poor quality, even-aged procedures such as liberation cuttings (in fact, the final removal of the shelterwood system) can be applied if advance growth is well established (1 metre or more in height); a two-cut uniform shelterwood can be employed if new regeneration is required. In this case, a seeding cut from below, retaining a crown density or canopy closure of 60 per cent should be employed. No site preparation is needed if the target species is sugar maple. Greatest protection to the developing understory is provided if the overstory is removed in winter. Regeneration should exceed 1 metre in height (before height increment begins to diminish) and should represent about 12,400 stems per hectare (Tubbs 1977a).

Dense second-growth sugar maple pole stands seldom contain much advance growth because of a lack of seed source. Thinning before 40 to 60 years of age will not stimulate much reproduction; however, tending through a rotation will usually result in a maple understory at maturity.

If the growth and quality of the stand is inferior because of site limitations (e.g. dry moisture regime; shallow soil; imperfectly drained soil; heavy-textured soil), conversion to other species such as pine or spruce (or in some cases aspen) is an option. The appropriate silvicultural guide should be consulted for regeneration prescriptions.

AMERICAN BEECH

A heavy-seeded, shade-tolerant species (similar to sugar maple), beech will reproduce on unprepared seedbeds in partial shade associated with single-tree selection. Higher residual densities (greater than 16 m^2/ha) favour the relative density of beech regeneration and its lack of browse potential aids its survival. Seed supply may be limited by bears foraging for mast. Beech generally does not regenerate well in stands where the canopy has been opened excessively, for example, in shelterwood cuts or clearcuts. In stands with overmature beech, thickets of root suckers may exist, most of which seem to have low potential to develop into larger timber unless specifically tended. The generally low timber quality of beech usually results in this species being marked for removal in improvement cuts. Retention of mast trees in uneven-aged practice will usually ensure a beech understory component while also providing food for wildlife.

WHITE ASH

A moderately heavy-seeded species that exhibits considerable shade tolerance at young ages, white ash can be regenerated without site preparation (especially in Site Regions 6E and 7E) using several methods. Uneven-aged stands containing white ash seed-trees often show good regeneration (Trimble 1965b), which must be favoured by release during partial cuts under the single-tree selection system prescribed for sugar maple. Group selection, employing small gaps, will favour white ash establishment and survival (Leak and Wilson 1958). Wind-dispersed seed will allow establishment in shelterwood and clearcut areas but seed viability is often low, with seeds exhibiting delayed germination. Thus the species seldom dominates reproduction in clearcuts. Stump sprouting is well developed and sprout stems often grow faster in height than seedlings do.

YELLOW BIRCH

Yellow birch regeneration can be secured if due consideration is given to the species' requirements for:

- an available seed source
- proper light conditions
- a receptive seed bed.

A light-seeded species of intermediate shade tolerance, yellow birch requires partial overhead shade on a very-fresh to moist sandy-loam site (MR 3-5), preferably with a telluric water table and a seedbed comprised of a mixture of humus and mineral soil (Burton *et al.* 1969). Maple and beech litter is a barrier to germinant rooting and must be removed in site preparation either by mechanical means (summer logging and deliberate pre-cut scarification to achieve 50 per cent coverage) or pre-harvest fall prescribed burning (after leaf-fall and before snowfall). Maple, beech or ironwood advance growth should be eliminated from the vicinity of the seedbed, using a herbicide if necessary.

Yellow birch can be maintained as an even-aged mosaic in an uneven-aged selection forest of sugar maple by employing group selection (Trimble and Hart 1961) and in fact, this approach has been applied with success on Ecosites 28 and 29. Since seed is wind-dispersed for long distances in early winter, acceptable levels of yellow birch regeneration can often be achieved by retaining a relatively small number (from 5 to 12) of good quality seed-producing trees per hectare throughout the stand and in the vicinity of the canopy gaps. The recommended diameter of the canopy openings is normally equivalent to the height of the stand (0.04 ha) and should never exceed 50 m (0.20 ha) in order to provide partial shade and exclude competitive intolerant species. Height growth will be maintained only if smaller canopy openings are expanded in future harvesting operations. Yellow birch is a favourite deer browse and may be seriously inhibited by heavy feeding pressure.

Yellow birch can be regenerated using a two-cut shelterwood system (Godman and Erdmann *no date*) on ES 28.2 and ES 30.2. The seeding cut is most effective when implemented during a good seed year (about every three years). Overstory canopy density or crown closure should be reduced to 50 to 60 per cent on scarified sites or 60 to 70 per cent on burned sites (Tubbs 1977b). Early mortality is high and successful stocking requires a minimum of 25,000 seedlings per hectare after one year. Under proper light conditions, first-year height growth should exceed 15 cm. Where overstory density is maintained at 70 per cent crown closure, some additional thinning may be required if regeneration does not maintain a height increment of at least 45 cm per year. The overstory should be removed when seedlings are 1.8 to 2.4 m tall. Under these conditions, yellow birch will dominate sugar maple of the same age, but the advantage disappears if canopy closure significantly increases. Yellow birch will regenerate without seedbed preparation only in the friable litter under hemlock, but growth is slow and seedlings seldom survive.

In stands of the northern transitional portions of Site Region 5E, where the site condition and quality of sugar maple suggests conversion to the better-adapted yellow birch, the regeneration technique will depend on accessibility. In addition to uniform shelterwood, a three-cut strip clearcut approach has been used, with strips about one tree-height in width. Cutting discriminates against sugar maple while yellow birch seed-trees are retained in each cut, scheduled six to seven years apart. In areas not readily accessible, a clearcut with seed-trees (evenly distributed at 50 to 60 m intervals throughout the area) could be employed as a basic management strategy, but with reduced expectations for stocking and future yield. Neither approach is effective unless the whole treatment package of available seed source, provision of light conditions sufficient to allow rapid growth of yellow birch regeneration while inhibiting development of intolerant species and creation of suitable seedbed is assured.

BLACK CHERRY

A heavy-seeded, relatively shade-intolerant species, black cherry will reproduce in fresh loams on unprepared seedbeds but requires overhead light to survive and grow. Since seed is often dispersed by birds into areas with no cherry in the overstory and because seed can remain buried in the organic layers in a dormant condition for many years, stand disturbance may give rise to black cherry stocking where none is expected (Auclair and Cottam 1971). The buried seed is not usually consumed in light prescribed surface fires and may, in fact, be stimulated to germinate as a result of such a disturbance.

Black cherry is most successfully reproduced, if a seed source is available, using group selection (0.04 ha) (Trimble and Hart 1961) or uniform or strip shelterwood (Marquis 1979) in which one third of the basal area is harvested. Once regeneration is established (greater than 1 metre in height), the overstory should be removed (Smith 1983) since height growth increases exponentially up to full light (Gottschalk 1985). This species usually outgrows hardwood associates, with the exception of aspen. It is often selectively and intensively browsed by deer (Hough 1959).

RED OAK

A heavy-seeded species of intermediate shade-tolerance, red oak is perhaps the most difficult tolerant hardwood forest species to regenerate consistently (Johnson 1979). It can reproduce without seedbed preparation, but infrequent seed crops and severe predation of acorns from wildlife and insects limit regeneration success. Regeneration is often easier to procure on drier sites (Trimble 1973; Hilt 1985b) but quality development and yield are best on fresh-to-moderately moist (MR 2-4) sites, especially those best described as protected “cove” sites.

There are at least 5 key elements that should be considered when trying to establish red oak:

- Manage red oak on sites where competition is limited or where sufficient tending resources will be committed to establish oak

- Retain numerous, vigorous seed trees to overcome seed predation and tree-to-tree variation

- Use overstory crown closure to control competition until red oak seedlings are established and vigorous

- Tend competing vegetation as required, taking advantage of oak’s natural ability to resprout with improved vigour

- Use one or more removal cuts to increase the light levels available to develop regeneration.

Dey and Parker (1996) recommend that when understory vegetation is abundant (e.g. ecosites 24.1, 24.2 and 25.1) residual crown cover after the first shelterwood cut should be at least 70 per cent. Under these conditions a cut resulting in a lower crown closure may result in severe understory competition. If the understory vegetation is sparse (e.g. ecosites 23.1 and 23.2) or has been reduced by vegetation management treatments the overstory could be reduced to 50 per cent in the initial cut.

If the initial shelterwood cut is a seeding cut it will work best if carried out during a bumper oak seed-crop year. This should provide adequate seed even in the presence of insect and animal predation.

Site preparation and subsequent tending to control competition will increase the potential for oak establishment. It may be advisable to control advance growth of tolerant species such as sugar maple or beech by herbicide (Johnson and Jacobs 1981) but care must be taken to avoid killing advanced oak regeneration (*see* Section 9.4.3 “Chemical site preparation”). Prescribed fire is another option (Johnson 1974) that combines site preparation and tending (***see*** Section 9.4.2 “Prescribed fire”). The approach will eliminate top growth, after which the oak should re-sprout and capture the site. In some cases, the process may be repeated sequentially to build up sprout vigour and stocking (2,500 stems per hectare) of oak before complete release.

If the regeneration is present but not yet well-established and the overstory has become closed, it may be necessary to do more than one removal cut to maintain good seedling crown form (Bey 1964). Shaded seedlings develop a flat-topped form which will show delayed height growth response to release (Carvell 1967). This could result in shade tolerant species dominating the regeneration. If the understory oak loses dominance, competition control may also be advisable prior to, or in conjunction with, one of the removal cuts (***see*** Section 9.2.2 “Shelterwood system”). The final overstory removal should be delayed until advance growth is dominant and well-established (i.e. basal caliper of 1.3 cm or height of 1.2 m).

Because the use of clearcutting techniques to regenerate oak has provided extremely variable and conflicting results, this method should be avoided until the current state of knowledge improves, except as a complete release of established advance growth (Johnson 1976).

BASSWOOD

Even though basswood is one of the heaviest and most frequent seed-crop producers among the hardwoods, trees rarely originate from seedlings under natural conditions (Godman *no date*). Basswood seed exhibits delayed germination (from eight months to seven years after dispersal) because of: 1) an impermeable seed coat, 2) a dormant embryo and, 3) a tough pericarp (Crocker and Barton 1957; Schopmeyer 1974; Erdmann 1983). During this time, rodents (mice, squirrels, chipmunks), insects and decay destroy much of the seed.

Winget (1968) noted that basswood was frequently an important contributor to harvested wood volumes in Quebec but was usually a minor component in resultant second-growth stands. Two years after a crown thinning in a 60-year old sugar maple-basswood stand in Ontario, Stroempl (1972) found that basswood reproduction had not improved. Despite the fact that 34 per cent and 24 per cent of the trees had produced seed in the first and second respective years following cutting, only 4.8 per cent of the seed found in the litter was sound. None of the residual trees produced any seed in the subsequent five years. Because of the prolonged after-ripening process of seed, Stroempl (1972) suggests that a heavy seed crop is required two years prior to harvest in order to establish basswood from seed.

Germination may occur sooner in humus layers where decomposition of the litter is rapid. Jarvis (1956) suggests that heavy cutting in basswood stands may increase seedling production by promoting germination due to enhanced litter decomposition. Prescribed fire, while presently untested, may produce suitable seedbed conditions. Fire will also tend to promote root-collar sprouting of basswood stumps in heavily cut stands (Perala 1974).

Basswood can germinate in the overstory shade conditions of uncut stands and seedlings and seedling sprouts will develop on dry to fresh sites where understory competition is not too dense. This regeneration requires early release as it is usually suppressed by maple and beech competition.

The uniform shelterwood system has occasionally been successful, primarily in the western part of basswood’s range where the species is more dominant. Generally, natural regeneration from seed is unpredictable and the requirements for establishing this species are largely unknown (Burns 1983).

In Ontario, Stroempl (1965) found a relationship between seed moisture content and seed coat permeability. Fruits collected early in the fall seed ripening period generally have a higher moisture content and a softer pericarp. These two factors result in a higher germinative capacity for the early-collected seed. Seed collected later in the fall can be conditioned for a higher germinative capacity by removing the pericarp, scarifying in sulphuric acid and soaking in kinetin and gibberellic acid and then storing at 4^{o} C for 2 months (Pitel and Wang 1988). Direct seeding of either type of seed into a suitable seedbed soon after heavy cutting may increase the probability of seedling establishment.

Cold storage of autumn-lifted seedling planting stock maintains root-growth capacity and seedling vigour for use in spring planting. Fall planting results have been poor (Stroempl 1971; Crow 1990).

While basswood cannot sustain itself as suppressed seedlings and saplings, even under partial canopies, the species is a prolific stump sprouter and regeneration in most areas originates from stump sprouts (Erdmann 1983). Basswood stems tend to be replaced in the canopy by these stump sprouts, which out-compete maple seedlings upon death of a dominant basswood stem (Bray 1956; Godman and Mattson 1976; Tubbs 1977a). This tendency is fostered by an early advantage of sprouts which are subsidized by the root system of the parent stump (Daniel *et al.* 1979) and an affinity of basswood trees to break off rather than to uproot (Runkle 1979). This literal self-replacement may occur for several generations of stems. In this manner, individual basswood trees may have extremely long life expectancies, capable of persisting on a single microsite for several generations of stems (Woods and Whittaker 1981). This may be considered to be a special case of gap-phase self-replacement. By means of this mechanism, the species can maintain significant representation in the canopy (Godman and Mattson 1976; Tubbs 1977a; Woods and Whittaker 1981).

Significant basswood regeneration can also result from seedling sprouts which arise from parent seedlings or saplings (stems less than 5 cm DBH). When damaged, a seedling usually breaks off at the ground line, producing an automatic low-origin sprout. These small stumps quickly callus over, thus reducing infection hazard. This type of regeneration, often a result of logging damage, grows faster than seedlings (Kelty 1988).

To encourage sprouting, parent trees should be cut during the dormant season (prior to bud break) to allow sprouts to harden-off prior to fall frost. Stumps should be cut as close to ground level as possible without damaging the bark of residual stumps. High stumps can be recut closer to the ground. Sprouts originating high on the stump will break away easily and do not develop an independent root system (Stroempl 1983b). Such sprouts are susceptible to decay transfer from the parent stump (Roth and Hepting [1943a, b]; Roth [1956]; Roth and Hepting [1969]). Established sprout clumps must be thinned early to promote growth and good stem quality (***see*** Section 9.6.1.6 "Stump sprouts").

9.4 Site Preparation

9.4 Site Preparation

by Harvey Anderson, Dan Dey, Andree Morneault, Brian Batchelor and Andy Mutchmor

Site preparation activities are normally implemented to meet one or more of the following objectives:

- to control severe competition
- to create a suitable seedbed in terms of moisture condition, texture, and continuity
- to redistribute slash
- to reduce compaction or improve drainage of surface soil.

Site preparation as applied in tolerant hardwood forests, usually emphasizes management of competition and seedbed conditioning.

Seedbed preparation is not usually required for medium- and heavy-seeded species of high or intermediate shade tolerance (hard maple, beech, white ash, red oak, and black cherry). In fact, it is often detrimental because many of these species regenerate from advance growth present prior to cutting, and some species (oak and cherry) regenerate better when covered by litter or buried in organic matter. Increased density levels of red oak regeneration following mechanical site preparation (Mutchmor and Batchelor 1996) have been linked to the blending or pushing into the soil of acorns by the prime mover, but further study related to treatment timing (seasonal and in relation to seed crop) and intensity is required. Site preparation is not a concern in uneven-aged management of most shade tolerant species.

Small- or light-seeded species such as yellow birch require specific seedbed conditions to establish successfully, such species preferring a lightly disturbed forest floor in which litter is removed and the organic layer and upper mineral soil horizons are mixed. Resultant control of competing vegetation before the establishment of the new crop provides better conditions for establishment and early growth. Yellow birch requires some overhead protection but will not survive intense competition from raspberry or maple advance growth.

Slash is not usually a problem in partial cutting systems where markets encourage high levels of utilization, and typical sites rarely need surface structuring. Heavy equipment is not required and extensive areas of treatment are not common. The exception is in the northern transitional forest, where strip cutting or seed-tree methods are used in single-species even-aged regeneration prescriptions.

There are three basic methods of site preparation: 1) mechanical, 2) prescribed fire, and 3) chemical. Each has its own characteristic effects, and the three are not mutually interchangeable although they often have synergistic effects when combined (***see*** TABLE 9.4.1). Useful overviews of site preparation methods are given by Sutton (1985) and Stewart (1978).

TABLE 9.4.1: Comparison of effects of site preparation methods (*from*: Stewart [1978])					
SIP METHOD	REMOVES DEBRIS	REDUCES COMPETITION	PREPARES SEEDBED	REDUCES COMPACTION	CREATES MICROSITE
Mechanical	++	+	+	++	++
Prescribed Burn	+	++	+	—	—
Chemical	—	++	—	—	—
Combination	+	+	+	+	+
++ VERY EFFECTIVE		+ EFFECTIVE		— NOT EFFECTIVE	

9.4.1 Mechanical Site Preparation

Physical disturbance of litter, slash and vegetation on the forest floor accompanies logging operations during skidding of logs and maneuvering of equipment on-site. Harvesting and log extraction activities may result in a crude cultivation of the forest floor, removal of leaf litter and compaction reduction. Logging operations alone normally result in relatively limited coverage (10 to 15 per cent) unless logs are deliberately channeled to separate skid trails; however, such a practice could lead to increased logging damage to residuals.

Planned mechanical site preparation treatments commonly employ bulldozers equipped with toothed blades or root/rock rakes to displace the litter layer on the forest floor and expose the moist decomposing layer of duff. The equipment can be used to uproot competing vegetation and to realign slash, but if not implemented with care, could result in displacement or removal of nutrients in the organic soil layers. The skill of the operator is more important than the type of machine in meeting site preparation objectives and minimizing potential site damage. Drag- type scarifiers such as 10-kg-link anchor chains equipped with gouging pins are effective in breaking up litter, ripping out established competition, and mixing the humus and mineral soil to create a suitable seedbed, which is so critical to light-seeded species such as yellow birch (Anderson and McCormack 1967).

Wheeled skidders may be employed in place of tracked vehicles, but must be used cautiously in wet weather to prevent rutting and erosion. Angle dozer-blades, root-rakes, and V-blades may be appropriate in strip cuts, where extensive mechanical site preparation is prescribed in post-harvest application. These tools can handle heavy slash accumulations and can root out undesired advance growth (Horton 1964).

Site damage can occur when mechanical treatments are done inappropriately or under adverse conditions. Factors that can influence the degree of site damage include: ecosite type, equipment type and it's use, soil characteristics, slope, and environmental factors such as season and precipitation. For a discussion on site damage, ***see*** Section 11.0 “Harvesting Considerations”.

Most mechanical methods are relatively expensive depending on site accessibility, machine type, and degree of treatment required. A review of current uses and trends of mechanized site preparation techniques is given in Smith (1987). An overview of silvicultural equipment appropriate for the tolerant hardwoods is given in Smith (1981) and Dominy (1987) and techniques appropriate for assessing their efficiency are described by Sutherland (1986).

ECOSITE CONSIDERATIONS

The mechanical site preparation considerations for the principal ecosites provided below apply to the "average" conditions found within those ecosites. Individual stands may have characteristics that deviate from the average. A careful and thorough site inspection should be done in all stands that are being considered for mechanical site preparation. Details related to the prediction and avoidance of site damage from mechanical site preparation, are provided in Section 11.0 "Harvesting Considerations".

9.4.1.1 Yellow birch - Ecosites 28.1, 28.2, 29.1, 29.2

Pre-harvest mechanical site preparation can promote yellow birch regeneration on ecosites 28.1, 28.2, 29.1 or 29.2, although slope may be a problem on some sites. Light mechanical site preparation, where the leaf mat is displaced without mineral soil exposure, can provide a good seedbed for yellow birch and some control over competing understory vegetation. However, for adequate control, hardwood trees and tall shrubs must be uprooted to prevent them from re-sprouting from the root collar. Various autecology guides (Bell 1991; Buse and Bell 1992; Arnup *et al.* 1995; Mallik *et al.* 1996; Buse 1992a, 1992b; Hollstedt 1992; Sims *et al.* 1990; Bentley and Pinto 1994; Louter *et al.* 1993) provide rooting depth information on these species (mineral soil *vs*. duff) to help plan the mechanical site preparation treatment. Red maple, for example, roots in the mineral soil and will require deeper mechanical site preparation than beaked hazel. Balsam fir and ground hemlock are easily controlled using mechanical equipment.

9.4.1.2 Red oak - Ecosites 23.1, 23.2, 24.1, 24.2, 25.1

Post-harvest mechanical site preparation as a component of the shelterwood system in red oak management may aid in the control of competing vegetation, and in the burying of acorns, thus reducing losses to desiccation and predation. This treatment may be sufficient to control competing vegetation on ecosites 23.1 and 23.2, but will likely need a follow-up chemical site preparation treatment or a tending treatment on ecosites 24.1, 24.2 and 25.1. All the ecosites in this group tend to be sloped. Field inspections to assess degree of slope and possible limitations to the use of mechanical site preparation equipment are warranted.

9.4.2 Prescribed Fire

Prescribed burns can either be done pre- or post-harvest. Pre-harvest burns are typically low-intensity surface leaf-fires, consuming fine fuels (twigs) and leaf litter only to the depth of the fermenting layer. They do not involve logging slash, and cause only minor and ephemeral ecological change (Anderson 1982). Post-harvest burns have been used for red oak regeneration and are usually scheduled after a shelterwood cut. Resultant fire intensities are usually greater because of increased fuel loads. In cases of stand conversion to conifer, techniques involving chemical site preparation followed by prescribed fire may be employed. The role of fire in forest site preparation in Ontario is described by Dixon (1982). Procedures for planning prescribed burns are described in *Prescribed Burn Planning Manual for Crown Lands in Ontario* (OMNR 1996b), OMNR Aviation and Fire Centre Procedure No. PR AF.03.23.02 (1980), *Prescribed Burning,* and *Forest Manager's Photo Guide to Prescribed Burn Planning* (Wearn *et al.* 1982).

Pre-harvest fall prescribed fire can promote yellow birch regeneration by preparing an adequate seedbed, eliminating seedling and small-sapling advance growth, and destroying most seed resting on the forest floor. Pre-harvest fall fires are run after leaf-fall (usually in mid-October), when maple and beech seed has fallen, but birch seed has not. Birch seed falls throughout the winter, is stratified in the melting snow, and ultimately lands on the burned seedbed. If logging is carried out subsequent to burning, incidental mechanical site preparation will occur to further enhance at least part of the seedbed. Planning a yellow birch fall burn is facilitated by the ability to forecast a seed year. During the fall prior to a good seed year, high numbers of male catkins can be observed on overstory trees.

Research work in the late 1950s and early 1960s at the Swan Lake Research Reserve in Algonquin Park (Anderson 1982) demonstrated that fall prescribed burning was effective at establishing yellow birch regeneration. However, few prescribed burns have been completed since then. The narrow burning window is a major impediment to the expansion of this program. Fire Weather Indices are set to reflect the weather needed to obtain the fire behavior that will meet site preparation objectives. After leaf fall, the temperature is cool (<20 C), relative humidity is high (>50 percent) and days are short. These conditions do not allow a rapid recovery of Fire Weather Indices and drying of forest fuels, especially after precipitation. The UPBX (Martell 1978), a computer program that examines past weather data, can be used to predict the number of days that would meet the prescribed Fire Weather Indices in a specific area of the province during a specific time period. For example, in North Bay, the burning window was estimated to be between October 15 (most hardwood trees have lost their leaves by then) and October 31 (usual date of first snow fall). Mark Derry (North Bay Fire Management, Ontario Ministry of Natural Resources) calculated that there was an average of only 1 day per year that met the prescribed indices within that burning window.

Godman (*no date e*) has shown that burning in the spring prior to a good yellow birch seed year can also enhance yellow birch regeneration. The burning window is longer (May 1 to June 15) and the potential number of days that would attain the appropriate Fire Weather Indices is larger (average of 17.3 days). A drawback is that a well-prepared seedbed in the spring will to some extent become covered with leaves again in the fall, before birch seeds are dispersed.

Post-harvest burns for red oak regeneration are often conducted in the spring, before leaf flushing of a majority of the vegetation has begun. Single fires are ineffective in reducing the amount of competition because many undesirable woody species that experience shoot-kill will produce sprouts (Loftis 1990). Repeated fires are required to reduce competition. Although the ideal number and frequency of prescribed fires for oak regeneration is currently unknown, the results of prescribed burning and fire history studies indicate that burning every 3 to 5 years favours oak regeneration (Nyland *et al.* 1983; Guyette and Dey 1995). More frequent burning in shelterwood cuts has not benefited oak reproduction. Three consecutive annual burns in a Bracebridge oak shelterwood have effectively reduced the amount of understory woody vegetation but have also promoted the dominance of bracken fern and adversely affected the red oak advanced regeneration (Mutchmor and Morneault 1995). Fire intensities are greater with increasing fuel loads and decreasing moisture contents of the logging debris. Pockets of fuel that have cured for several years can produce high fire intensities. Under these conditions, the probability of fire-caused mortality of the residual overstory increases for trees near slash concentrations.

Fire-caused mortality of red oak reproduction varies with seedling age. Both Johnson (1974) and Mutchmor and Morneault (1995) have found that one prescribed fire in the spring caused 60 to 70 per cent mortality of 1-year-old red oak seedlings. However, mortality was only 30 to 40 per cent for seedlings that were at least 3 years old. Spring fires can cause significant reductions in acorn viability (Auchmoody and Smith 1993). When stands have produced good to bumper acorn crops, understory burning should be delayed for up to 3 years to allow sufficient time for germination and seedling establishment.

Burning may not be economically practical or efficient in group selection, where the patches are relatively small (0.2 to 0.4 ha), although it is certainly feasible and can be successfully practiced if conditions warrant the time and effort on a local scale. This would be done only to maintain even-aged patches within an uneven-aged stand. The approach is applied more easily under shelterwood methods where the treated areas are more extensive and contiguous.

Burning is relatively cost-efficient (per net hectare treated) but is subject to the uncertainties of weather and is less selective in terms of avoiding areas of concern. Considerable skill is required to execute prescribed burns, although application techniques have been well researched for use in yellow birch regeneration (Burton and Sloane 1958; Holowacz 1960; Sinclair 1962; Sykes 1964; Burton *et al.* 1969; Anderson 1982).

ECOSITE CONSIDERATIONS

The prescribed burning considerations for the principal ecosites provided below apply to the "average" conditions found within those ecosites. Individual stands may have characteristics that deviate from the average. A careful and thorough site inspection should be done in all stands that are being considered for understory burning.

9.4.2.1 Red oak - Ecosites 23.1, 23.2, 24.1, 24.2, 25.1

Fire has played a key role in maintaining the red oak component on these ecosites. Fire alters the structure and composition of vegetation in favour of species that are fire tolerant and whose reproductive strategies are promoted by fire. The drier and less herb rich ecosites (23.1 and 23.2) will likely need fewer fires to promote red oak regeneration than the moister, richer sites (25.1). Ecosites 23.1, 23.2, 24.1 and 24.2 are good candidates for understory burning to promote red oak regeneration. On ecosites 23.1, 24.1 and 24.2, advanced red oak regeneration will likely sprout more vigorously after a fire than the sugar maple and ironwood. Balsam fir in the understory will be killed by one fire. Red maple, which produces numerous sprouts in response to top-killing by fire, will continue to be a competitor. Depending on the density of red maple in the understory of the specific site being managed, more than one fire may be required to maintain the dominance of red oak regeneration. Fire will provide an improved seedbed for white pine (an overstory component on ecosites 24.2, 23.1 and 23.2) and hemlock (Ecosite 23.1), which may regenerate if there is a good seed crop following the fire. Ecosite 23.2 has a higher cover of sugar maple, ironwood, and red maple in the understory and a higher cover of tall shrubs such as beaked hazel than the other ecosites in this group. The higher moisture regime indicates a higher level of competition. Ecosite 23.2 also has less advanced red oak regeneration, so some effort may be required to promote regeneration through planting or seeding either before or after a prescribed fire. Well-established planted red oak will produce vigorous sprouts following a fire.

Carefully assess the number of aspen in the overstory and understory as they will be stimulated to produce root suckers following a fire. When planning the prescribed fire, be aware of slopes on these ecosites: on average, over 85 per cent are on slopes, with over 40 per cent being on the upper slope position. Slope has a strong influence on fire behaviour and intensity.

9.4.2.2 Yellow birch - Ecosites 28.1, 28.2, 29.1, 29.2

Fire can be used on these ecosites to prepare a seedbed for yellow birch regeneration and to top-kill the competing hardwoods in the understory. Fire will control the balsam fir in the understory and will temporarily reduce the density and vigour of sugar maple, red maple, mountain maple, striped maple, and beaked hazel, but they will re-sprout vigorously. Depending on the density of understory hardwoods and tall shrubs on an individual site, another site preparation or a tending treatment (chemical or manual) may be necessary to provide adequate control. The fire will consume the litter mat on the surface of the forest floor exposing a moist humus seedbed. Advanced yellow birch and hemlock regeneration, if present, will be killed by the fire.

9.4.3 Chemical Site Preparation

Herbicides may be used to kill unwanted vegetation in order to reduce competition and prevent potential re-sprouting. It is efficient in terms of time and often relatively inexpensive. However, it leaves the forest floor physically undisturbed and therefore does little to create seedbeds suitable for light-seeded hardwoods.

Herbicide application must be planned and executed by licensed individuals with knowledge and training in the use of chemicals registered for forestry use (Province of Ontario 1994; Ontario Weed Committee 1995), in accordance with OMNR Forest Resources Branch Procedure No. FR 04.20.10 (1990), *Aerial Application of Herbicides for Forest Management in Ontario*. For general information on the use of herbicides, refer to McLaughlan *et al.* (1996) and Williamson and Lane (1989). For information on chemistry, uptake and translocation, mode of action, and formulations, consult the "Herbicide Handbook" (Ahrens 1994) and technical notes published by the Canadian Pulp and Paper Association. Information extracted from these sources has been summarized in TABLE 9.4.2 and TABLE 9.4.3. For up-to-date information on rates and use, consult product labels.

Herbicide effectiveness depends on choice of chemical, target-species' susceptibility, method and timing of application, and immediate weather conditions. The use of chemicals alone as a site preparation method is limited to cases where competing vegetation is susceptible, slash density is low, and litter is not a barrier for the species to be regenerated. For information on the susceptibility of specific species to the different herbicides, consult the appropriate autecology guides or information notes (Sims *et al.* 1990; Bell 1991; Buse and Bell 1992; Buse 1992a, 1992b; Hollstedt 1992; Louter *et al.* 1993; Bentley and Pinto 1994; Arnup *et al.* 1995; Mallik *et al.* 1996). For detailed information on the equipment and methods used to apply herbicides, refer to: Otchere-Boateng and Ackerman (1990), Desrochers and Dunnigan (1991), and McLaughlan (1992).

The use of herbicides as a site preparation tool in tolerant hardwood forests is limited to only a few specific circumstances. This tool has potential for use in managing yellow birch and red oak by controlling low competition prior to seedling establishment under the shelterwood system. Chemical site preparation can be used as an alternative or in combination with mechanical site preparation or prescribed fire. The principal advantage of herbicide use is the prevention of re-sprouting from the root or root collar, a condition that occurs frequently and vigorously following light surface fire or mechanical site preparation.

Herbicide application to control understory trees taller than 1.5 m or larger than 1.5 cm in DBH can be beneficial to the establishment, survival and growth of oak reproduction (Johnson *et al.* 1986; Loftis 1990; Schlesinger *et al.* 1993; Lorimer *et al.* 1994). Herbicides (e.g. glyphosate) can be applied by tree injection, by basal or foliar spraying, or to the cut stumps of the taller competing understory and sub-canopy trees. Application to stumps is done at the time of cutting, regardless of season. Cutting alone has not been effective in reducing competition, especially on higher quality sites, because many of the trees produce sprouts which grow rapidly in the open. Basal spraying and tree injection can be done any time of the year. Basal spraying is especially effective and easy to apply on trees less than 2.5 cm in DBH or when there are dense clumps of small diameter trees. Foliar sprays are applied during the growing season, but efforts must be made to protect advanced oak regeneration. This can be accomplished by directed spraying or by cutting the oak reproduction before herbicide application. The oaks will subsequently sprout and should grow well with less competition.

Red oak has been successfully regenerated without large advanced regeneration present before overstory removal when herbicides are used (Johnson and Jacobs 1981; Crow 1992). Johnson *et al.* (1989) reported that oak regeneration comprised one-third of the basal area in a Wisconsin clear cut 11 years after harvest. The understory had been controlled with several pre-harvest applications of herbicide. The first herbicide application was done 2 years before clearcutting and the second occurred just before harvesting. A bumper acorn crop in the fall before the harvest set the stage for abundant new red oak seedlings.

TABLE 9.4.2: Active ingredient, trade names, Pesticide Control Product number (PCP), and permitted use for 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	DowElanco Release® Silvicultural Herbicide	A/G	A/G			*	*
2,4-D amine	16994	Dow Formula 40F Forestry Herbicide			*			*
	16995	Clean Crop Forestamine® Liquid Herbicide for Forestry			*			*
	18067	Clean Crop Sure-shot® 5000 Liquid Herbicide			*			*
	18075	Clean Crop Sure-Shot® Forestamine			*			*
	18113	Sanex Amine 500 Forestry Herbicide			*			*
	11441	Van Waters and Rogers Guardsman® 2,4-D Amine 500 Liquid Weedkiller			*			*
2,4-D ester	15981	Dow Esteron® 600 Forestry Herbicide	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 9.4.3: Five most common herbicides available for use in forestry (*adapted from*: Arnup *et al.* 1995; Otchere-Boateng 1990; McLaughlan *et al.* 1996)

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, cherry, hazel, blueberry, sweetfern, rubus spp., bracken fern, willow, alder, *etc*.). Poor control of tough-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®: ground application to actively growing vegetation. For site preparation (late June to late July). 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. 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 1992). More effective on moist vegetation and 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).

TABLE 9.4.3: Five most common herbicides available for use in forestry (*adapted from*: Arnup *et al.* 1995; Otchere-Boateng 1990; McLaughlan *et al.* 1996)					
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 broadleaved leaves. Does not control sedges or grasses. Not effective on maple or oak species (Sajdak 1985). Resprouting 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: ground application for site preparation. 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. 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^{o}C (Boyd *et al.*1985).
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® 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.* 1996)	Absorbed through the roots, translocated upward through the xylem, photosynthetic inhibitor. Residual and contact control. Tolerant plant species are able to metabolize doses of herbicide which susceptible species cannot.	Velpar® L: Broadcast ground application and undiluted spot treatments for site preparation release. 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, 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. 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.

TABLE 9.4.3: Five most common herbicides available for use in forestry (*adapted from*: Arnup *et al.* 1995; Otchere-Boateng 1990; McLaughlan *et al.* 1996)

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 (Ontario Weed Commission 1995)	Absorbed through plant roots by mass flow with water and dissolved ions. Translocated upward in plant through xylem.	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.
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 ground application as foliar spray, early June-July; 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.

9.5 Artificial Regeneration

9.5 Artificial Regeneration

by Harvey Anderson and Al Corlett

9.5.1 Direct Seeding

The use of direct seeding to regenerate the various species of the tolerant hardwood forest is a supplementary silvicultural technique usually employed in cases of seed-crop failure, inadequate catch of natural regeneration or lack of available planting stock. The technique has been used in Canada since 1900 but between 1900 and 1972, direct seeding of tolerant hardwood species amounted to only 0.7 per cent of the total area seeded (Waldron 1973). Techniques include broadcast application and/or seed-spotting in scalped seedbeds. In some cases, density control is a problem if uneven dispersal occurs. Much of the mechanization recently developed is more applicable to boreal species than to species of the tolerant hardwood forest (Brown 1973).

Guidelines for forecasting and collecting tree seed are given in *Guidelines for Tree Seed Crop Forecasting and Collecting* (OMNR 1986b). Most species require stratification to effect rapid germination; this normally occurs over winter. Some species, like hard maple, germinate at cold temperatures (1° C to 2° C) (MacArthur and Fraser 1963), often beneath snow cover. Therefore, they are often seeded in nurseries in the autumn (Carl and Yawney 1977). There is usually little need to artificially seed sugar maple in forest conditions. Yellow birch, a frequent associate of sugar maple, germinates at higher temperatures and usually later in the spring, a fact that offers a competitive disadvantage to birch in some cases (Tubbs 1965). Direct seeding of yellow birch has been successfully carried out at both the experimental level (Hatcher 1966; Roberge 1977) and the operational level (Ashenden 1957). Tests of direct seeding of black cherry have had negative results unless the seed is buried (Huntzinger 1964).

Red oak is the species that benefits most from direct seeding because of its general difficulty in regeneration. Tree-collected acorns are more viable than those collected on the ground (Teclaw and Isebrands 1986), but germinative potential can be increased by eliminating cull acorns using salt flotation (230 to 285 g NaCl per litre of water, depending on moisture content) as described by Johnson (1983). Pericarp removal will modify dormancy and greatly increase the germination of freshly collected acorns (Hopper *et al*. 1985). Godman and Mattson (1980) recommend stratifying acorns over winter and pre-germinating them by slightly raising temperatures for 12 to 14 days. Acorns treated in this manner should then be seeded immediately after snowmelt in spring to take advantage of favourable cool temperatures and to minimize predation. Sowing acorns at a five-centimetre depth may favour establishment (Johnson and Krinard 1985).

The specific recommendations of Godman and Mattson (*no date*) for direct seeding of hard maple, white ash, yellow birch, hemlock, and red oak are summarized in TABLE 9.5.1.

TABLE 9.5.1: Recommendations for direct seeding of species in the tolerant hardwood forest (*from*: Godman and Mattson [*no date*])		
SPECIES	SITE PREPARATION	SOWING RATE (per hectare)
sugar maple	none	3.4 - 10.0 kg
white ash	none	2.2 - 7.8 kg
yellow birch	mixed humus/mineral	0.13 - 0.37 kg
hemlock	mixed humus/mineral	0.37 - 0.74 kg
red oak	scarify or burn	1235 - 3700 acorns

9.5.2 Planting

All species which grow in the tolerant hardwood forest can be successfully planted under properly prepared conditions. However, such measures are undertaken only when the alternatives are limited—for example:

- when natural regeneration or direct seeding attempts have failed
- to introduce genetically improved stock
- to introduce special species mixtures
- to improve wildlife habitat
- to achieve afforestation in open fields or on idle land.

FOREST PLANTINGS

Regeneration by planting is usually carried out in conditions where the survival potential of seed-based systems is low (e.g. in older cutovers), or a dedicated under-planting is prescribed using a species that is otherwise difficult to regenerate (e.g. red oak in a shelterwood stand).

Godman (*no date* c) stressed the importance of matching site to species, top-pruning stock, using large stock, planting immediately after site preparation, creating proper overhead canopy conditions, and planting groups of a single species or mixing species that have similar growth rates and habits.

Planting of species such as yellow birch, hard maple and white ash is usually confined to conditions where natural regeneration is difficult to obtain (Hannah and Turner 1981; Gottschalk and Marquis 1982; Francis and Bivens 1985).

Perhaps the most important application of forest planting is that of red oak, a species noted for its reproductive inconsistency. Considerable success has been achieved in the Missouri Ozarks using a four-step prescription (Johnson 1984b; Johnson *et al*. 1986). The recommended treatment in the Ozarks is underplanting 1+1 red oak stock with a minimum basal diameter of 10 mm. The stock is clipped back to a 15 cm top length prior to shipping. It is planted under a shelterwood overstory thinned to 60 per cent stocking (the "B" line of Gingrich [1967]). The overstory should be removed after three growing seasons. Competition is partially controlled by applying an appropriate herbicide to tree stumps and cut stubs of unwanted woody understory vegetation prior to planting. A second herbicide treatment is applied at the time of overstory removal. To prevent herbicide damage where a foliar application is used (e.g. glyphosate), oak reproduction can be cut off at ground level before the herbicide is applied; the oaks will re-sprout the following year. Under this prescription, one-third to one-half of planted trees (in Missouri) are expected to successfully establish (achieve *free-to-grow* status) two years after the shelterwood overstory is removed. Table 9.5.2 indicates the estimated number of planted seedlings needed to attain a specified target density after shelterwood removal in relation to initial basal-stem diameter. Johnson (1984b) also found that for trees planted directly into clearcuts, the probability of successful establishment was greater for container-grown stock than for any class of bare-root stock for a given basal diameter.

TABLE 9.5.2: The number of planted red oak needed to establish a specified density (in Missouri) by the end of the treatment period (*modified from*: Johnson *et al*. [1986])

INITIAL BASAL DIAMETER (MM)	PROBABILITY OF SUCCESS	NUMBER TO PLANT FOR ONE SUCCESS	NUMBER/HA TO PLANT TO GET 1200/HA ESTABLISHED
1 + 0 AND 2 + 0 SEEDLINGS			
4	0.04	20.00	24 000
8	0.18	5.56	6 672
12	0.33	3.03	3 636
16	0.44	2.27	2 724
1 + 1 TRANSPLANTS			
4	0.06	16.66	20 040
8	0.29	3.45	4 080
12	0.53	1.89	2 280
16	0.63	1.59	1 920

- seedlings clipped back to 15 cm above base before planting
- assumes shelter removed between third and fourth growing seasons
- an established tree has annual net height growth of 40 cm for 2 years after shelterwood removed

Similar studies conducted in central Ontario by Stroempl (1986) and Gordon *et al*. (1995) used prescriptions similar to that of Johnson (1984b) but included the use of spring prescribed fire and a variety of reproduction techniques such as acorns germinated in tubes and spot-sown acorns.

Many nursery and container stock types and sizes are available to the forest manager, with implications to survival, early establishment and long-term productivity. Choice of stock type will depend upon the basic ecology of the area to be reforested, tolerance to competition of the target species, site requirements, etc. Johnson *et al*. (1996) provides some direction on the selection and planting of hardwood container and bareroot stock in Ontario.

OPEN-FIELD PLANTING

Open-field planting is an activity that has been restricted primarily to private land in southern Ontario. However, opportunities to do this type of planting sometimes arise in other parts of the province. These situations are usually related to amenity planting, afforestation of open land that reverts to the Crown or where forest production is deemed to be an appropriate land use. Reliable overviews of techniques and prescriptions for this condition are given by Von Althen (*no date*) and OMNR (1977). Selecting a proper planting site, site preparation, post-planting weed control, planting-stock quality, planting method, and rodent control are identified as major factors affecting plantation establishment and success (Von Althen 1979a, 1979b). Godman (*no date* c) notes that effective weed control in plantations will help alleviate severe rodent damage and seedling mortality. Russell (1971) recommends deep planting of oak seedlings to increase establishment success.

Prescriptions for planting and tending red oak, sugar maple, white ash, and black cherry have been outlined by Von Althen and Webb (1980) and Von Althen (1974a, 1979a, 1979b).

9.5.3 Conversion to/from the Tolerant Hardwood Forest

Some sites support a forest type that may not be ideally suited to that particular site. For example, white pine may occupy a deep rich site as a result of fire or some other disturbance. While the current forest may have performed very well in the past, an encroaching, aggressive hardwood understory may severely hamper efforts to regenerate pine on that particular site. Another example may be a rich site occupied by a poplar stand, again as a result of past disturbance, which may or may not have tolerant hardwood species in the understory. In both cases, a forest manager may wish to develop the new crop as a tolerant hardwood type. This can be accomplished either by releasing adequately-stocked established hardwood regeneration through liberation cuttings, or by augmenting the existing regeneration through seeding prior to release. Techniques used to establish red oak in conifer plantations by underplanting have been demonstrated by Stroempl (1987a, 1987b). Subsequent management would be in accordance with concepts and procedures outlined in this guide.

Conversely, hard maple (i.e. ES 27.1) or hard maple and red oak (ES 23.1) may be aggressive on dry, nutrient-poor sites, where they will grow relatively slowly and have low-quality potential.

One option may be to manage the hardwoods extensively for fibre products only. However, it may be more appropriate to convert the site to a more productive working group such as white pine, a species more adapted to these conditions. In such cases, the hardwoods might be used as a "nurse crop"; doing so would involve carrying out a shelterwood cut to control light intensity, implementing site preparation to control the hardwood understory competition, and finally, establishing the pine by direct seeding or planting. Specific procedures for conversion from a tolerant hardwood to a conifer forest type are contained in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario.*

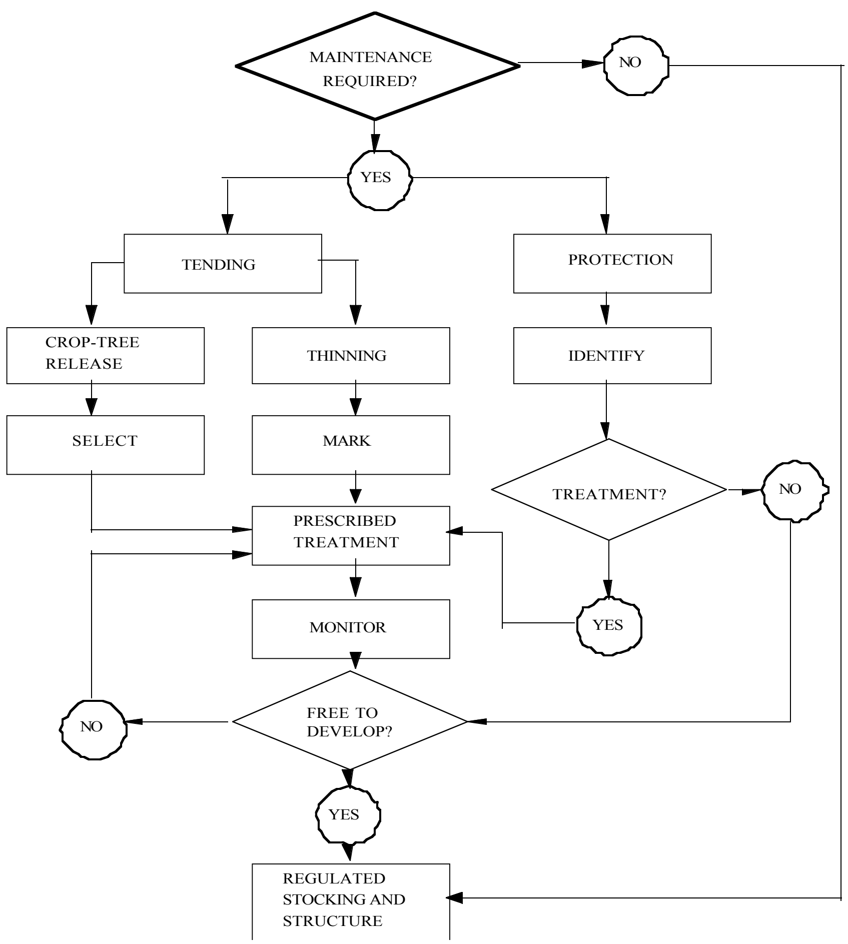
9.6 Stand Maintenance

9.6 Stand Maintenance

by Harvey Anderson, Scott Reid and Joe Churcher

Once a stand has been regenerated, it must be maintained and protected, from establishment to maturity, by a series of intermediate treatments. These treatments ensure survival, regulate the growth of the developing stand, and may provide early financial returns. Not all treatments may be necessary to maintain quality and vigour depending on species, site, markets, and the silvicultural system being used. In the selection system, harvesting, regenerating, and tending (often combined with sanitation cuttings) are carried out simultaneously rather than in a staged sequence. Protection measures include recognizing and controlling important insect and disease pests (***see*** Section 4.0 "Silvics") of each species, and using planning techniques designed to avoid excessive logging damage. A conceptual model of the decision process in evaluating tolerant hardwood forest maintenance requirements is given in FIGURE 9.6.1.

FIGURE 9.6.1: A decision model to assess maintenance requirements of developing hardwood stands (Anderson *et al.* 1990)



9.6.1 Tending

Tending procedures are designed to ensure continued productivity of forest stands by:

- increasing the volume growth and the value growth of selected crop trees
- shortening veneer- and sawlog-tree rotations
- improving tree quality and species composition
- increasing total yield of products by salvaging high-risk trees and smaller individuals that would otherwise die.

Treatment response in diameter and height growth will vary with species, size, crown position, crown vigour (crown size, live crown ratio, foliage density) and available growing space (Erdmann 1987). TABLE 9.6.1 summarizes the various types of tending treatments that may be considered in tolerant hardwood management.

Treatments aimed at regulating species composition and improving the quality of young stands are called "release" cuttings. These are divided into three types:

1. ***cleanings*** - which are made in a sapling stand to free the best trees from undesirable individuals of the same age that overtop them
2. ***weedings*** - which remove all plants competing with crop species regardless of their competitive status
3. ***liberation cuttings*** - which free young sapling stands from competition involving older, overtopping individuals.

It should be noted that, because both cleaning and weeding procedures not only are prohibitively expensive but also may be detrimental to the stand if not properly applied, they should be considered only for small areas of unique value (e.g. ANSI locations, gene pools, etc.). A conservative but effective alternative is to encourage seedling and sapling stands to grow undisturbed until crowns have closed and merchantable lengths of clear bole are established appropriate for the species and the site class.

Treatments aimed at regulating species composition and improving the quality of older stands (i.e. those past the sapling stage) are called *improvement* cuttings. They remove trees of undesirable species, form, or condition (such as overmature or leaning individuals) from the main canopy.

TABLE 9.6.1: Summary of intermediate treatments carried out in stand maintenance (*from*: Beattie *et al.* 1983)

ACTIVITY	STAGE	PURPOSE	TREES REMOVED	TREES RETAINED
Release Cutting				
Cleaning*	Sapling	Regulate species composition and tree quality	Unwanted species and trees of poor form	Crop-tree species of good form.
Weeding*	Sapling	Regulate species composition	Unwanted species	Crop-tree species
Liberation	Seedling/ sapling	Release young stand	Older, larger overtopping trees	Seedling/sapling regeneration
Improvement Cutting				
	Pole and larger	Improve species composition and improve quality	Unwanted species and poorly formed, overmature trees	Well-formed, desirable species with good potential
Thinning				
Low thinning	Pole and larger	Salvage mortality and reduce root competition	Lower crown class	Middle/upper crown class
Crown thinning	Pole and larger	Increase crop-tree growth and salvage mortality	Poorly-spaced trees in upper crown class	Well-spaced, well-formed trees in upper crown class
Pruning				
	Pole - Max DBH 20 cm	Improve lumber quality		

* Usually not cost-effective under operational conditions and may be detrimental to the stand if improperly applied.

Treatments aimed at controlling stand growth are called *thinnings*. These regulate the distribution of growing space for the advantage of the existing crop. Thinnings may be made from above (crown thinning) or from below. *Crop-tree thinning* considers individual trees as candidates for a final crop and releases their crowns to allow development of high-value products. Thinnings for high-value products in the tolerant hardwood forest should be done only on this basis.

Stand maintenance may also include procedures to increase bole quality through eliminating branches by *pruning*. In the tolerant hardwood forest this is often accomplished by *natural* or *self-pruning*, which results from maintaining proper stand density. Some situations justify *artificial pruning* to accelerate value increment.

Using herbicides for tending purposes in the tolerant hardwood forest is uncommon. Most herbicide use involves converting stands from hardwood to conifer, where the hardwoods have established on sites that are relatively unproductive (for hardwoods). Such sites have normally been site-prepared and planted after cutting under the uniform shelterwood or clearcut systems.

Tolerant hardwood species are unique in that any cutting in the stand will affect bole quality through changes in stand composition, stem form, clear-bole length, merchantable height, insect or disease incidence, climatic effects, and tree growth. Godman and Erdmann (1983) have summarized some of the factors affecting tree quality:

- Stem forking:

  Caused by loss of terminal bud resulting from bud miner, frost, or leader breakage. This problem is common in maple, ash and birch; recovery rate is related to stand density and is delayed or prevented by excessive crown exposure.

- Epicormic branching:

  Caused by flushing of dormant buds on the bole following exposure after thinning. It is not serious on trees with large, healthy crowns.

- Limb-free length:

  Affected by rate of branch mortality and shedding due to side-shade. It is related to stand density. Acutely-angled branches are often associated with natural-pruning defects (bark inclusions, stain, *etc*.).

- Stem canker:

  Nectria on yellow birch and *Eutypella* on maple jeopardize the survival of affected stems.

- Climatic influences:

  Sunscald injury to polewood is promoted by excessive thinning on exposed sites with southerly aspects.

Identifying potential crop-tree quality is an important first step in all tending procedures for high-value products. Crop-trees of any species should have the following characteristics:

- desirable species (By, Or, Cb, Aw, Mh, Bd)
- dominant or codominant healthy crowns only (also intermediate crowns of shade-tolerant species)

- good form—butt log of grade 1 potential
- straight bole and clear for 50 per cent of height, ideally developing 7.5 to 10 metres without branches or V-shaped forks
- free of major surface defects or internal decay
- free of black knot (Cb), *Nectria* (By), or *Eutypella* and sugar maple borer (Mh).

Specific guidelines on these factors are noted in Section 5.0 "Quality Development in Trees."

Subsequent procedures differ depending on the management strategy and silvicultural system used. Godman (1986) suggests a few general rules for improving stand growth and quality in stands in the Lake States:

- Consistently maintain proper stand density. When in doubt, leave a slightly higher stocking
- Select to leave the best individual, uniformly spaced crop-trees, within stocking and structure guidelines, using crown size and stem form
- Never cut below 12 m^2/ha of basal area (in trees larger than 10 cm DBH), even if undesirable trees have to be retained
- Recognize stand variation during the marking process.

Standards developed in the southern part of Site Region 5E recommend minimum stocking levels of 11 m^2/ha (10 cm DBH and larger) of basal area in selection and shelterwood stands, and 14 m^2/ha in even-aged polewood hardwood stands.

9.6.1.1 Uneven-aged stands

For uneven-aged tolerant hardwood stands managed under the selection system, regeneration, harvesting, and tending are combined into one operation in periodic cuttings. Tending of intermediate age classes occurs in the process of structuring a stand (***see*** Section 6.2 "Stand Structure") to achieve a balance in the growing space allocated to different diameter classes (Nyland and Marquis 1978). In high-graded or unmanaged stands, this is accomplished by improvement cuttings, the major goal of which is to concentrate or transfer growth to the best-quality trees in the stand by removing overmature, cull, or wolf trees. In defective stands, where no market exists for low-quality material, overstory stems may have to be eliminated by girdling or applying herbicide. This would result in a more gradual release to the advance reproduction. As a result of this treatment, cull and defect characteristic of overmature stands become minimal after the third cyclic cut, provided that logging damage is controlled.

Many cull trees die after logging. In the northeastern United States, 39 per cent of the residual culls over 18 cm DBH died within five years and 46 per cent were dead within ten years due to shock from sudden exposure, and windthrow. Mortality was even higher for smaller cull trees. It is recommended that large (marked) culls be eliminated before, during, or immediately after logging. Smaller culls may be left for five years since 40 per cent may die within this period, and cull developing from serious logging damage could be assessed and remedied if necessary at the end of the five years (Trimble and Smith 1963).

The selection method of cutting offers an excellent opportunity for an appreciable reduction in the proportion of cull in hardwood stands. After three selection cuts, Trimble (1965a) found that sawlog defects were reduced progressively, amounting to 20 per cent, 8 per cent, and 5 per cent of gross log scale. By the third cutting, the proportions of sound and defective material had stabilized and the process of reducing cull was finished. Volumes of cull can be maintained at one per cent or less of gross sawlog volume, and stands may be expected to produce sawlogs with average scaling deductions of 4 to 5 per cent.

Similarly, Cooley (1964), working in Michigan, found that much cull in poor-quality stands is caused by overmaturity or mismanagement and that cull development does not progress as rapidly as harvest under proper application of the selection system. In sawtimber trees existing at the beginning of the study, the percentage of unmerchantable volume decreases from 40 per cent to 28 per cent to 4 per cent after one, two, and three harvests, respectively.

Trimble (1963) noted that the development of new cull trees is remarkably slow in managed stands from which culls had been removed. New culls developed mainly as a result of logging damage, but cull-tree elimination should be only a minor and periodic operation after one thorough initial treatment has been made.

Bole quality of smaller trees, especially of hard maple, tends to improve with increased stand density (Godman and Books 1971) and increasing site quality. Cutting in sapling classes is unnecessary. It is important to move polewood stems into the main canopy to maintain a relatively dominant crown position capable of continued satisfactory growth while at the same time maintaining stocking in polewood clumps to ensure continued self-pruning to the lower 7.5 to 10 metres of bole. Pole-sized trees benefit most from cuttings that leave no more than 14 to 16 m^2/ha of basal area. The duration of response depends on the degree of cutting and the cycle length must vary with cut intensity and rate of re-growth by the residual stand. Unlike less-tolerant species, hard maple is “elastic” and will tend to respond to release even at an advanced age and often after significant suppression. In hard maple stands, structure is maintained by recruitment into saplings and poles from advance reproduction commonly available on the forest floor. The height-growth response of small seedlings to varying degrees of release indicates that there is little response from light cutting. Over a typical 20-year cutting cycle, there is a linear response in average height increment as residual overstory basal area (10 cm DBH class and larger) is reduced from 22 m^2/ha down to 10 m^2/ha. Further reductions in basal area, however, do not produce greater height-growth response—and, in fact, may decrease it. Cutting to recommended stocking levels in the southern part of Site Region 5E on appropriate sites should result in average height increments of about 25 cm per year in hard maple seedlings and saplings over a 20-year cutting cycle. It should be noted that cutting below stocking targets (***see*** Section 6.1 "Stand Stocking") to accelerate structural recruitment will cause some loss of residual volume growth (OMNR 1983).

In instances where stand analysis (***see*** Section 9.1.3 "Stand analysis") indicates that quality potential is poor and the overstory should be eliminated, a liberation cut (***see*** Section 9.2.2 "Shelterwood system") should be carried out to fully release advance reproduction of hard maple. In this case, average height increments could be expected to be 50 cm per year over the 20-year cycle, and even more in the most vigorous stems. Such development would put the stand into polewood in the 21 to 40 year age class. This will produce an essentially even-aged stand, which should be tended accordingly (***see*** Section 9.6.1.2 "Even-aged stands").

Cultural work in the understory of uneven-aged forests is generally less beneficial to the residual stand than cultural work in the overstory. However, when group selection (or patch cutting) is practiced (for example, to encourage yellow birch to regenerate within the uneven-aged forest), there are better possibilities for such procedures in the essentially even-aged young growth (Leak and Filip 1975). Tending at each cutting cycle entry is required to eliminate overstory crown encroachment as required to maintain a free-to-grow condition.

9.6.1.2 Even-aged stands

Even-aged stands may arise through deliberate activities such as shelterwood or liberation cuttings, or due to exploitive situations involving clearcutting (such as for chemical wood or fuelwood). Where few veteran overstory residuals remain, the resultant condition is often referred to as "second growth". Stands often contain a mixture of trees of desirable and undesirable species, quality, and origin. Good overviews of the results of various tending treatments applied to even-aged hard maple, yellow birch, red oak, white ash, and black cherry are provided by Erdmann (1987, 1983) and Lamson and Smith (1987). Some general recommendations for tending are presented in TABLE 9.6.2.

Even-aged stands may be cultured to maturity over time using a series of cuttings designed to favour desirable stems and maintain them in a dominant or "free-to-grow" condition.

TABLE 9.6.2: Recommended even-aged tending techniques for valuable hardwood species			
SPECIES	STAGE OF DEVELOPMENT		
	Sapling	**Pole**	**Sawlog**
yellow birch	Cleaning not necessary if species captures site. Potential crop trees must maintain live crown ratio > 25%.	Delay crop-tree release until stand closes and bole clear length is 8 metres. Crown release about 250 trees per hectare.	Maintain dominant crown position of crop trees by removing two important competitors. Maintain even-aged stocking guide levels.
hard maple	Cleaning not recommended.	Delay crop-tree release until stand closes and bole clear length is 8 metres. Crown release about 250 trees per hectare.	Maintain even-aged stocking guide levels or convert to uneven-aged structure and stocking guide levels.
black cherry	Clean only to maintain survival. Delay at least until age 12 for growth response.	Release crop trees before age 40 or before crown ratio falls below 40%.	Maintain crown position, size, and vigour of crop trees to avoid loss. Maintain even-aged stocking guide levels.
white ash	Cleaning will maximize ash component but dominants will usually survive without treatment.	May need heavy release to avoid mortality due to suppression in tolerant mixture. Trees will resist epicormic sprouting.	Maintain crown position of crop trees. Maintain even-aged stocking guides or cut to 16 m^2/ha of basal area.
red oak	Control competition with manual cleaning, herbicide or fire within ten years.	Thin low-origin sprout clumps to best stem before DBH exceeds 5 cm. Suppressed stems respond to release but may produce epicormic branches.	Maintain even-aged stocking guide levels. Stop thinning at age 60 years.

Cleaning

This treatment is not usually recommended in sapling stands because it is expensive and is a long-term investment. Such pre-commercial release is attractive only in stands managed intensively for high-value products (Higgs 1981), where in some studies return on investment has been found to be as high as 6 to 10 per cent (McCauley and Marquis 1972). Methods for economic evaluation of management decisions have been demonstrated by Olson *et al.* (1978); Leak (1980); Gunter (1983); Hynard (1984); LeDoux (1986). Cleaning is not recommended until dominant stems can be recognized. Mixtures of species such as black cherry, red oak, yellow birch, and white ash have benefited from early release. However, ill-conceived treatments can delay natural pruning and promote epicormic branching, low forking, and sunscald, and otherwise adversely affect quality (Nyland and Marquis 1978). Traditional cleaning and weeding, where it can be justified, will eliminate undesirable species (such as aspen) and poorly formed individuals (such as sprouts).

Sprout-origin red oak benefits from cleaning whereby clumps are thinned to the best single stem of low origin before diameter exceeds 5 cm..

Cleaning should be carried out only when necessary to maintain survival and stocking of potential crop-quality trees of the desired species of intermediate shade tolerance. Erdmann (1983) recommends cleaning yellow birch saplings when they constitute less than 50 per cent of stocking. The need is minimized, however, by regeneration techniques that achieve a higher proportion of preferred species. For example, where group selection and fall prescribed fire are used, 95 per cent of reproduction may consist of yellow birch, due to the selectivity of the reproduction technique. Such groups of saplings are usually in need, however, of liberation cuttings in which the original canopy gaps are enlarged as the regeneration occupies the opening. This usually occurs as part of a normal single-tree selection cut at the next cycle. This type of release is also appropriate where poor-quality veteran residuals occupy the site to the extent that they interfere with development of regeneration.

Crop-tree release

If pre-commercial cuttings are considered, they should be applied only on a crop-tree basis to concentrate investment on the stems with the best quality potential. Subsequent treatments are designed to maintain designated trees with a favourable crown position until harvested. It is recommended that about 250 crop trees per hectare be selected in pre-commercial operations in southern parts of the province and perhaps 375 per hectare in the northern transitional forest. Limiting the release treatment to this level will greatly reduce expenses and carrying charges without adversely affecting yield. This will allow for future intermediate harvest and some mortality to sustain about 150 trees per hectare (a fully-stocked stand) at the end of the rotation. Growth response of tolerant hardwood forest species to various pre-commercial crop-tree release treatments have been studied by Wendel and Lamson (1987); Lamson (1983); Erdmann *et al.* (1981, 1975a, 1975b); Hannah (1978); Lamson and Smith (1978); Trimble (1974); Erdmann and Peterson (1972); Marquis (1969); Drinkwater (1960); Conover and Ralston (1959); Church (1955); Stoeckeler and Arbogast (1947); Downs (1946).

In stands where site quality or location preclude intensive early cultural measures, the even-aged stocking guides (***see*** APP. D), though not intended for pre-commercial use, may be used as rough approximations for stand treatment. In such cases, not more than 50 per cent of basal area should be removed during any treatment, and response levels can be expected to be less favourable than with more intensive methods.

Shade-tolerant species such as hard maple (and beech) can be carried for 30 years or more without treatment (preferably until removals are marketable) because they will not significantly deteriorate from moderately intensive inter-tree competition. This will promote clear-bole development at the expense of diameter growth, but the live crown ratio of potential crop trees should be maintained at levels above 30 per cent. Stems designated for removal should be felled or girdled if the operation is pre-commercial.

A similar approach can be applied to the mid-tolerant (inelastic) species such as yellow birch, but considerably more attention must be given to maintaining adequate live crown ratio (greater than 30 per cent) on the potential crop trees. Occasionally, this may be a problem in overstocked stands or in cases where overstory removal was significantly delayed, resulting in crown recession by age 25 years, which may not be recovered even after release. In these instances, pre-commercial crop-tree selection and release may be an option. Potential crop trees can be effectively released prior to extreme crown recession by freeing the crown ("complete crown release") through removal of neighbours that restrict crown expansion (Erdmann 1983). A similar procedure, called "crown touching", removes any tree (except another crop tree) whose crown touches the crop tree or overlaps above or below it (Lamson and Smith 1987). No trees are removed unless doing so will benefit a crop tree. Following crown thinning, diameter growth rates often will be twice that of untreated stems and will be concentrated on better-quality trees. Neither basal area nor spacing is given prime importance in young stands. The correct selection and release of potential crop trees is the main basis for treatment. Stem quality will not usually be affected (because of the previously rapid self-pruning) as long as the crowns close again prior to the first commercial thinning.

Where economically feasible to release greater numbers of stems per acre, the "D + (Imperial unit)" rule may be useful. Stoeckeler and Arbogast (1947) used "D + 2" as a rule to determine release radius in young northern hardwoods. In this method, all competing trees are removed within a radius equal to the crop-tree DBH + 2, numerically substituting feet for inches (i.e. a DBH of two inches would give a release radius of four feet). The metric equivalent to this rule is approximated by the equation:

$$\text{Radius (m)} = 0.605 + 0.12 * \text{DBH (cm)}$$

A similar (Imperial unit) rule for oak (D + 1) has been recommended by Johnson and Godman (1983).

While using chainsaws to cut competing trees is considered cheaper than using herbicides, release effects may be short-lived if vigorous re-sprouting occurs. In such cases, the technique of Wendel and Lamson (1987) is appropriate; it involves administering a 20 per cent aqueous solution of glyphosate by stem injection at intervals of 4 cm edge-to-edge around the base of all stems larger than 2.5 cm in basal diameter. Applying 1.5 ml of solution per incision effectively controls re-sprouting of target stems.

In oak regeneration, cleaning can be accomplished using prescribed fire. Two burns, four years apart, effectively control sprout competition while the oaks are able to re-sprout and grow without serious difficulty (Nyland *et al.* 1983).

Thinning

Market conditions and the degree of stand development often dictate which thinning methods are possible. The advantages of early thinning do not occur before crowns close, inter-tree competition becomes important, and crop trees self-prune to desired clear length. The first practical thinning in hardwood stands is often postponed until they reach “commercial” pole size (15 to 20 cm in DBH and 7.5 to 10 m in clear length), and this is usually impractical before age 40 years. White ash, yellow birch, and black cherry usually respond best to thinning before age 40 and thus may require pre-commercial treatment. Being “inelastic” species, they will not respond favourably to release from the crown-depleting effects of crowding at later ages. On the other hand, hard maple stem form usually benefits from delayed release; it can respond favourably even after considerable suppression. Hibbs and Bentley (1984) developed a growth model for red oak (perhaps also applicable to other semi-tolerant hardwood forest species), which suggested that thinning before age 45 would reduce potential financial returns, due to the tradeoff between merchantable height and diameter growth rather than to the cost of pre-commercial thinning. The value lost in merchantable height (from lack of self-pruning) is not compensated by the value gained in additional diameter growth induced by thinning. A rotation of about 95 years would maximize returns. The timing of the first thinning is therefore a compromise between shortening the rotation and optimizing the effects on bole quality and value.

When the average stand diameter reaches “commercial” size in the southerly range of the tolerant hardwood forest (15 cm DBH with about 23 m^2/ha of basal area at 40 years (Murphy *no date* b), the stocking guides provided by Tubbs (1977b) can be used to regulate stocking levels. When adjacent crowns touch, resulting in lower-branch mortality, the “average” line of the stocking guide has been reached, representing the best balance between individual tree growth and quality development (Erdmann 1987). In pole stands, basal area of trees 10 to 15 cm DBH and larger should not be reduced to less than 14 m^2/ha or left at more than 20 m^2/ha. Reducing density by 30 per cent will seldom lead to sunscald or epicormic branching. Light appears to play an insignificant role compared to crown position and size in the development of epicormic branches (Books and Tubbs 1970). In mixed species, stands should be cut from below to 60 to 70 per cent *relative density,* and thereafter, thinnings to remove about 20 per cent relative density should be scheduled at 15-year intervals until final harvest (Stout 1987). By the age of 60 years in southerly portions of the range, average stand diameter should have increased to 25 cm DBH and thinning should be done to maintain growth on the best stems and to prevent crown depletion (Murphy *no date* b). Stands in the northern transitional forest may require additional time (up to 25 years) to attain this condition (Bruce and Heeney 1974). For best growth and quality development, Erdmann (1987) recommends leaving increasing amounts of basal area and decreasing numbers of trees as stand average DBH increases, to maintain stocking guide levels. The technique of “rule thinning” developed by Rogers and Johnson (1985) may be useful for oaks and other species in meeting stocking goals during thinning treatments.

In small-sawlog-size stands (25 to 30 cm DBH), selective thinning can be carried out to free codominant crop trees from their two most important crown competitors. This activity should not remove more than one-third of the basal area. In the later, mature stages of even-aged management, a few overstory trees can be cut to favour crop-tree growth without seriously reducing total volume production, but this approach should be limited to salvaging high-risk, cull trees without creating large canopy holes. Stocking should not be reduced below 18 m^2/ha, nor should more than 28 m^2/ha be retained. The last thinning should leave only enough high-quality trees (about 150 final 45 cm DBH trees per hectare) to completely utilize the site.

With regular crown release and thinning schedules, yellow birch 45 cm DBH and of veneer grade can potentially be grown in 87 years. Without this tending, it could require an additional 60 years (Erdmann 1987). Similarly, Nyland and Marquis (1978) estimate that proper treatment should produce hard maple with a DBH of 50 cm in 80 years with a mean stand diameter of 38 cm in the northeastern United States.

In even-aged management, the final thinning (at about 80 years) would be in the form of a reproduction cutting, usually a type of shelterwood. The final liquidation of the stand would occur when the new crop is successfully established.

9.6.1.3 Converting even-aged to uneven-aged stands

Studies of cutting methods in second-growth stands in Wisconsin by Erdmann and Oberg (1973) have produced recommendations for developing uneven-aged stands from second-growth even-aged stands of shade-tolerant hardwoods (Godman 1986; Erdmann 1987). Most even-aged stands are overstocked with polewood and understocked with sawlog trees compared to the uneven-aged guides produced by Crow *et al.* (1981) and Arbogast (1957). Therefore Q-values of 1.6 to 1.7 (for 5 cm DBH classes) are more appropriate as a guide for the first cut. With recommended treatment, a Q-value of 1.3 can be achieved. It is suggested that marking concentrate on balancing basal area stocking in three sawtimber sizes rather than applying only a single stocking level of 14 to 20 m^2/ha (10 cm DBH and larger). In situations where management objectives require a conversion, the following procedure modified from Erdmann and Oberg (1973) may be applied:

- Starting with a 50-year-old polewood stand with crop-quality trees averaging 15 to 20 cm DBH and with 7.5 to 10 m of clear length, structure and quality should be quickly developed by crown release and should favour about 125 of the best dominant and codominant crop trees per hectare. Crown release a radius of two metres beyond the crown perimeter of polesized crop-trees or remove two important poor-quality crown competitors next to small sawlog-size crop trees. Ideal full occupancy of crop trees would space them about 10 m apart, but only good crop trees should be selected. Do not cut good crop trees unless competing with other crop trees

- Remove high-risk, cull, and defective overstory trees

- At each cutting, create 10 to 12 crown openings per hectare, each about 10 m in diameter, by removing any large overmature trees or groups of poor-quality poles. Make a patch cut if possible to remove small stems down to 5 cm DBH. This will encourage establishment and recruitment of tolerant-species regeneration to ultimately develop into a single mature tree in each gap

- The first thinning in 12 to 23 cm DBH pole-sized stands should be from below (beneath crop trees) to the minimum stocking level of Tubbs's (1977b) guide (***see*** APPENDIX D "Socking Charts"). Such cuts are heavy enough to get a good growth response but may be pre-commercial if markets for small material do not exist. In this case, initial entry into the stand may have to be postponed to age 60 years if investment opportunity is not available. This thinning should bring the stand back to a basal area of 14 m^2/ha (DBH 10 cm +)

- For optimum quality development, the second thinning should be delayed for about 20 years until crown closure develops and lower branch mortality (self-pruning) occurs on the crop trees. This second cut should concentrate via selection on improving quality development in the three sawtimber size classes as well as creating canopy gaps for regeneration. This cutting should reduce stocking to the *average* level of Tubbs's (1977b) guide, which will depend on the average stand diameter

- The third cutting should be according to selection stocking guide recommendations. A 45-year-old even-aged stand should be fully converted to selection after three cuts

- A decision pathway for this conversion is presented in Figure 9.1.1.

9.6.1.4 Hemlock-hardwood stands (ES 28.1, ES 28.2, ES 30.1, ES 30.2)

For Lake States stands overstocked with sawlogs, Tubbs (1977b) recommends that basal area first be reduced to 23 to 35 m^2/ha. A salvage cut should be planned within five years in overmature stands (post-logging decadence in hemlock). Subsequent cutting should reduce stocking to 24 m^2/ha (10 cm DBH and larger) on a ten-year cycle.

9.6.1.5 Pruning

Natural or self-pruning in tolerant hardwoods will be adequate at recommended residual stocking levels (***see*** Section 6.1 "Stand Stocking") to shed all limbs on the lowest two logs of crop trees. In areas of good access, the stem quality of high-value species in understocked stands can be improved by artificial pruning (Heeney 1974). Murphy (*no date a*) suggests situations in which hardwood pruning may be justified, including:

- plantations with only 1,700 to 4,000 stems per hectare

- sporadic regeneration volunteering on agricultural land

- 15 to 30-year-old woodlots in which stocking is low (500 to 1,700 trees per hectare), usually resulting from a pasturing history.

The objective of deliberate pruning is to produce clear wood (knot-free) on the bole of crop trees on a shorter rotation than would be possible through natural pruning.

Pruning is a long-term investment that should be performed only on potential crop-quality trees of dominant or codominant crown class. It may return 8 to 12 per cent on investment, especially if trees are at least 15 cm DBH when treated. It is usually coupled with thinning to stimulate growth rate, callusing, and upper crown development. Some studies suggest profitability if growth rings can be maintained at three rings per centimetre or better (Smith 1962). Methods of evaluating the economics of pruning are given by Smith (1954b).

Unlike conifer management, in which a specified number of trees per hectare are pruned, hardwood management involves pruning on an individual-tree basis in which only a few (5 to 10) low branches or early forks are removed from each tree (Skilling 1959a, l959b). It is recommended that only the butt log be pruned (i.e. to a height of 5 m) for best returns and that this pruning should not exceed 50 per cent of total tree height. Removal of dead lower branches has no effect on growth rate. Pruning should be delayed for two or three years after thinning to allow a build-up in crown vigour to suppress epicormic branching (Godman and Marquis 1969).

Tendency to produce epicormic branches after pruning or other disturbance varies with species (Trimble and Seegrist 1973; Smith 1966; Blum 1963; Skilling 1957). In oaks, there is some evidence that epicormic branching may be genetically controlled, and Carvell (1971) suggests that oaks exhibiting this tendency should not be pruned. Both black cherry and red oak are very prone to epicormic branching. Hard maple and beech are less affected and white ash rarely produces epicormic branches following pruning. Yellow birch tends to produce more epicormics than hard maple. Most affected species are less susceptible in stems of dominant or codominant crown position, especially when the crowns are well-developed. Red oak may show a greater susceptibility on poorer sites (Site Index 18) compared to better sites (Site Index 24). Artificial pruning does not tend to increase final clear length in unthinned stands of hard maple, but can significantly increase clear length in thinned stands by 30 per cent (Conover and Ralston 1959).

9.6.1.6 Stump sprouts

Stems originating vegetatively as coppice or sprouts from cut stumps or fire-killed tops can produce crop-quality stems and high-value products, often on shorter rotations than seed-origin trees. However, they must be selected and tended appropriately to achieve their potential. A good overview of tending methods for hardwood sprouts is given by Stroempl (1983).

Sprouting ability differs among species and often varies with parent-tree size, age, and vigour, stand density, and years since disturbance. Among hardwood species, basswood is the most prolific sprouter, significantly greater than black cherry, white ash, red oak, and hard maple in respectively decreasing order. Yellow birch sprouts poorly enough to be considered a non-sprouting species. From a regeneration point of view, white birch and ironwood, considered undesirable species (except for wildlife value), have more prolific sprouting ability than all except basswood, red oak and black cherry (Powell and Tryon 1979; Perala 1974; Solomon and Blum

1967). In hard maple, sprouting ability and sprout development are influenced by stand age, parent-tree size, and stand density. In cutover mature stands, the percentage of stump sprouting declines significantly with parent-tree diameter, stand density, and age of cutover. Sprout survival also decreases with tree size and years since cutting. In second-growth stands and young poletimber, neither stand density nor tree size influences sprout production (Church 1960). Clear cutting stimulates prolific sprouting in maple (Tubbs 1977a). Solomon and Blum (1967) found that the vigour of sprout production varied inversely with the age of the parent tree. Although hard maple has significant sprouting ability, the desirability of extensive areas of maple coppice is considerably less than that of red oak, black cherry, or white ash. Nevertheless, adequate tending can produce good-quality stems from maple coppice and it can serve a useful role in areas understocked with trees of seed-origin.

In red oak and black cherry, however, the proportion of stumps that sprout, the number of sprouts per stump, and dominant sprout height are not correlated with parent-tree vigour or parent-tree DBH according to Wendel (1975). Keetch (1944) notes that sprouting in oak is more prolific following fire in a stand of small trees (DBH less than 13 cm) than in polewood- or sawlog-size stands of Appalachian hardwoods. The stump sprouting capacity in red oak increases with stem diameter and tree age up to a threshold, beyond which it decreases (Sander *et al.* 1984; Johnson 1994; Dey and Parker 1996). Oaks less than 20 cm in DBH and 80 years old are good sprouters.

Sprouts originating from seedlings or saplings usually produce acceptable stem quality. Those originating from larger or older trees usually are not acceptable for high-quality timber production because of poor survival, poor form, and probability of stump rot. Large stubs of dead companion sprouts with mature-wood connections usually result in butt rot in the surviving sprouts (Tubbs 1977a). Oak stump sprouts that originate from below the ground produce high quality mature trees (Johnson 1994). Oak stump sprouts smaller than 7.5 cm DBH can be thinned without risk of decay. Clumps greater than this size can be thinned if they have low-origin “U- type” junctions. Stems with V-type junctions or from older stumps should be either completely cut or left entirely (Roth 1956). Sprout clumps arising after fire usually originate at the root collar. Using prescribed fire as a tending tool for red oak will therefore tend to produce oak sprouts of favourable origin and with good quality potential.

The difficulty of satisfactorily regenerating red oak increases the importance of using sprout material as prime growing stock. Johnson and Godman (1983) suggest that, under even-aged management, oak sprout clumps are good choices for pre-commercial thinning; however, these advantages do not materialize unless the clumps are selected properly and thinned early.

Stroempl (1983a) noted that it is most practical to thin to two or three sprouts per clump before age 20, later reducing the clump to a single stem. Early clump thinning to a single stem will maximize diameter growth of individual stems, depending on stand density level, site quality, crop-stem diameter, age, and relative basal area (i.e. ratio of stem basal area to clump basal area) after thinning. It is necessary to remove competitors every ten years to sustain maximum growth (Johnson and Rogers 1984). However, large sprouts that occupy about 50 per cent of the total basal area of the clump grow at approximately the same rate whether thinned or unthinned (Johnson and Rogers 1980).

An approximate thinning radius for sprout oak, given by Johnson and Godman (1983), is known as the "D + 1" rule; it approximates the maximum tree-area growing-space requirement for red oak and is equivalent to the "B-level" line of the oak model developed by Gingrich (1967). A growth simulator known as "COPPICE" has been developed by Rogers and Johnson (1982); it accurately predicts ten-year diameter growth for red oak in Wisconsin.

Basswood trees generally have narrow crowns in relation to their stem diameter (Godman and Tubbs 1973). This effectively reduces the species' growing space requirements so that stands comprising appreciable amounts of basswood can carry relatively high basal area stocking levels compared to other northern hardwood species. Tubbs (1977b) provides a stocking guide which suggests that stands with 20 to 49 per cent basswood should support basal area levels 15 per cent higher than typical northern hardwoods, for the same quadratic mean diameter. Stands containing more than 50 per cent basswood can be stocked at even higher levels.

Inter-clump thinning radii can be derived from known maximum growing space requirements for various species in stocking guides formulated by Gingrich (1967), Roach (1977), and Tubbs (1977b) among others. They provide information for deriving average spacing around trees at different stocking levels. In general, thinning radii around crop stems should not exceed average tree distances represented by the "B" level stocking (or its equivalent) as defined in the stocking guides. These distances vary by species and tree diameter (Johnson and Godman 1983).

This reduced growing space requirement for basswood is reflected in the work of Stoeckeler and Arbogast (1947). For 11-year old basswood sprouts, thinning radii of 0.75 m and 1.5 m produced similar 8-year DBH growth in clumps thinned to 2 or 3 stems; in contrast, the larger thinning radius was required to produce a similar response in hard maple, white ash, and American elm.

Subsequent thinnings (e.g. at 10-year intervals) around each crop stem will be required to maintain growth (Johnson and Godman 1983). Depending on stand composition and age at final harvest, intensively managed stands might produce from 25 to 125 stump sprouts per hectare. Stump sprouts originating from earlier thinnings are not likely to contribute significantly to the new stand because few stumps sprout under partial cuts (Church 1960) and any that do occur will probably die from suppression.

Johnson and Godman (1983) suggest the following guidelines for thinning oak clumps:

- Select stands on better sites
- Thin clumps when they reach 5 cm in DBH and definitely before 7.5 cm DBH
- Select the largest single stem that is well attached to stump at or below ground level and not connected to another stem

- For larger stems (greater than 7.5 cm DBH), the lower 5 m of stem should:
  - be free of sweep, crook, seams, fork, or decay
  - be free of V-connections with other stems
  - show little evidence of epicormic branching.
- Thin around crop stems to provide adequate growing space and to optimize growth and quality (use “B-level” stocking guide)
- Early clump thinning of red oak to one stem should produce a commercially mature stem (in Wisconsin) 20 years earlier than for trees of other origin.

Stroempl (1983) gives additional suggestions for encouraging the development of sprout clumps of northern hardwoods:

- To encourage sprouting, cut parent trees in dormant season
- Re-cut high stumps closer to the ground to encourage more sprouts to originate below ground
- Cut damaged or otherwise unsuitable advanced growth during cleanings to produce desirable seedling sprouts.

9.6.2 Forest Protection

9.6.2.1 Insects and diseases

Insects and diseases that are native to a particular area play an integral role in any forest ecosystem. Insects are part of the food chain; both insects and pathogens accelerate the level of decay of organic matter on the forest floor; and they are both examples of natural depletions which remove 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. In other cases, some management practices may actually accentuate the effects and spread of some pests e.g. the removal of only healthy trees during a *selective* harvest, leaving the weaker, diseased and more susceptible stems. In this example, decisions made during the tree marking operation could lead to the removal of many of the infected stems, thus decreasing the level of disease incidence and simultaneously improving the health and vigour of the forest.

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. The major insect and disease pests for each of the tree species discussed in this silvicultural guide, along with other important damaging agents, are included in the Section 4.0 “Silvics”.

9.6.2.1 Hardwood decline

Forest decline involving hardwoods has been documented in North America since the early 1900s (McIlveen *et al.* 1986). It is a complex disease caused by the interaction of a number of interchangeable, specifically ordered abiotic and biotic factors that produce a gradual deterioration, often ending in death of trees (Manion 1981). The syndrome usually involves at least three factors, one from each of (i) predisposing, (ii) inciting, and (iii) contributing categories. The central hypothesis is that stress of biotic or abiotic origin alters the tree's health and renders it susceptible to further loss of vigour. Disease organisms ultimately attack the weakened trees, resulting in their demise (Houston 1981).

Visual symptoms of stress and decline are outlined by Skelly *et al.* (1987) and Malhotra and Blauel (1980). Among the most obvious symptoms seen in Ontario are the following:

- abnormally small and chlorotic foliage
- premature fall coloration
- late spring bud-break
- early leaf abscission
- progressive crown dieback starting with fine twigs at periphery and working inwards
- wounds heal slowly
- bark eventually sloughs off

- increased epicormic sprouting (in tufts)
- loss of starch (food) reserve
- slow growth.

Historically, decline has affected a variety of species under varying circumstances. Individual episodes of dieback have been noted for white ash, red oak, beech, hard maple, yellow birch, black cherry, and basswood in the past. The current appearance of decline in Ontario commenced in the late 1970s, fluctuating in intensity with time and affecting many species. Decline is not unprecedented in Ontario but the current situation is unusual in the variety of sites and species affected.

Several ongoing decline monitoring programs are supported by MNR, notably the North American Maple Project, and the Ontario Hardwood Decline Survey. Through the Ontario Hardwood Decline Survey, a joint project of the Ontario Ministry of Environment and Energy (MOEE) and the MNR, annual surveys of forest health have been conducted. For each location sampled, a "decline index" (DI) is calculated by species based on the percentages of dead branches, chlorotic leaves, and undersized leaves in the tree crowns. The resulting decline index scale varies from 0 (healthy) to 100 (dead).

On the basis of such analyses, McIlveen *et al.* (1989) assessed the mean decline index for nine hardwood species in Ontario in 1986. In decreasing order of health (increasing mean DI) among the nine species, the ranking was as follows:

- hard maple ranked first (DI=12)
- beech ranked second (DI=13)
- white ash ranked third (DI=17)
- basswood ranked fourth (DI=18)
- yellow birch ranked fifth (DI=20)
- red oak ranked sixth (DI=20)
- black cherry ranked ninth (DI=28).

On a relative scale, trees with a DI of 12 and lower would be considered healthy. A DI of between 13 and 20 identifies a tree in a light decline class. A DI of between 21 and 30 represents a tree in a moderate decline class. Trees with a DI between 31 and 50 are in a high decline class, and over 50 is severely declining (McLaughlin *et al.* 1992).

These average values vary from year to year, fluctuating with a variety of current factors. The decline severity for all species considered together also varies with location in Ontario. In 1996, McLaughlin (1996) analyzed ten years (1986 to 1995) of monitoring the hardwood forests of Ontario. Ten-year mean decline index values associated with the Forest Regions and Sections of Ontario (Rowe 1972; ***see*** FIGURE 2.1.1), were calculated as follows (Mclaughlin 1996):

- 1986 to 1995 mean decline index is highest (DI=20) in Sudbury-North Bay (L.4e)

- relatively high values are also found in Georgian Bay (L.4d) (DI=18), Algonquin-Pontiac (L.4b) (DI=17), and Algoma (L.10) (DI=16)

- Comparatively low values (less than DI=14) are seen in Niagara (D.1) (DI=13), Huron-Ontario (L.1) (DI=12), Middle Ottawa (L.4c) (DI=11), Quetico (L.11) (DI=11), and Upper St. Lawrence (L.2) (DI=10).

Tree condition was consistently and significantly poorer in forest sectors on poorly buffered, acid-sensitive soil types in central Ontario than in forest sectors on well-buffered soils in the southern part of the province. The first ten years of monitoring indicated that the hardwood forest in Ontario, on average, is both healthy and stable. Annual fluctuations in mean tree condition were, with specific exceptions, marginal and largely explainable in terms of known and/or natural stresses. The interpretation of the data is complicated by the presence of significant pollution and climate gradients and the variety of soil types and conditions. None-the-less, when the data are examined from basic ecological principles, as opposed to overall means or arbitrary strata, patterns are apparent that clearly show tree condition is poorer in areas with both moderately high pollution deposition and acid-sensitive soils (McLaughlin 1996).

While the causal factors for decline have not been clearly defined, the epidemiology appears related to known stress events. Climatic episodes (thermal stress, precipitation stress) and insect defoliation (especially from forest tent caterpillar and oak leaf shredder) appear closely related to episodic symptom development. Somewhat similar symptomology seems to have been elicited by different inciting agents in different locations and species. Ash dieback has been triggered in the past by drought; beech, maple, and oak decline can be precipitated by insect defoliation; and birch dieback may have been associated with climatic stress. Secondary agents such as *Armillaria mellea* often accelerate symptom development by causing root rot. The maple decline situation in Ontario was relatively stable during the 1985-96 period, even showing improvement in some locations. The severe drought and insect infestation in 1988, however, caused the condition of maple to worsen significantly in previously affected areas.

Air pollutants such as sulphur dioxide, nitrogen oxides, and ozone are additional stresses imposed upon an already-stressed ecosystem. The nutrient-leaching effects of acid deposition are well documented (Foster and Nicolson 1984; Foster 1985; Innes 1987). A major portion of Ontario receives high annual loadings of acidic precipitation and sensitivity maps have been prepared to rate the soils and bedrock of Ontario in their ability to reduce the acidity of atmospheric depositions (Cowell 1986). Almost 32 per cent of Ontario consists of highly or moderately sensitive areas that receive potentially damaging annual loadings of wet sulphate. The most critical of these is the Muskoka region, where the impact is reflected in a relatively high decline index rating.

While forest managers cannot control most of the inciting factors associated with forest decline, they must deal with the condition in prescribing silvicultural treatments. Choosing appropriate sites and recognizing decline symptoms not attributable to normal aging processes or lack of proper management in the past are critical. A simple stress-detection critical pathway table is illustrated in Anderson and Rice (1993). In a "decline scenario," one option to be considered should always be delaying treatment until a proper diagnosis and remedial prescription can be made by consultation with appropriate knowledgeable authorities. On the other hand, some planning procedures should take account of the probable effect of predictable insect infestations on the health of species growing on sites sensitive to both climatic and pollution stress. Perhaps the best approach is to concentrate intensive management on the sites least sensitive but most appropriate for the species (McLaughlin 1987). Proper forest management is critical, sound silvicultural practices will improve individual tree vigour and increase overall forest productivity. Inadequately managed forests are not only less productive but the trees are less vigorous. Less vigorous trees are more susceptible to infection by secondary decay organisms and are damaged more easily by environmental stress. Therefore, forests that are inadequately managed may be predisposed to decline (McLaughlin 1992).

10.0 HABITAT MANAGEMENT CONSIDERATIONS

10.0 Habitat Management Considerations

by Brian 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 forested habitats; an additional 36 species live mainly in non-forested habitats but use riparian (shoreline) forest (e.g. beaver). One or more ecosites or development stages within the tolerant hardwood forest represent preferred (i.e. highly suitable) habitat for about 120 of the forest-dependent species. About 50 more species make occasional use of the tolerant hardwood forest. One species (white-footed mouse) is found only in tolerant hardwood forest; 16 species find preferred habitat only in tolerant hardwood forest (***see*** Bellhouse and Naylor 1997).

There is considerable variability in the degree to which species use tolerant hardwood 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 forest development stages used
- size of habitat patches required
- interspersion of habitat patches required
- special habitat components needed (e.g. cavity trees, downed woody debris).

How can the habitat needs of all species using the tolerant hardwood 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.

10.1 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]) in conjunction with forest management planning. Silvicultural practices should be modified at both 1) the stand or operating block scale (10s to100s 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.

10.1.1 Landscape Scale

ECOSITES AND DEVELOPMENT STAGES

FIGURE 10.1.1 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. The 8 tolerant hardwood ecosites cluster together and are generally distinct from those in the conifer or poplar-dominated ecosites (with the exception of poplar-white birch forest [ES 17] and pine-poplar-oak forest [ES 14]). Thus, the first step in managing habitat for wildlife that use the tolerant hardwood forest requires application of silvicultural practices that ensure that tolerant hardwood forest is perpetuated across the landscapes of central Ontario.

Within the tolerant hardwood forest, wildlife communities are very similar among some ecosites (e.g. ES 25 to 29 and 35) (FIGURE 10.1.1). However, wildlife communities differ substantially among others (ES 25 to 29 *vs.* ES 23 and 24). Moreover, individual ecosites differ in the number of species that use and/or prefer them (TABLE 10.1.1) and no two ecosites support the same combination of species (Bellhouse and Naylor 1997). Thus, silvicultural practices applied in the Great Lakes-St. Lawrence forest should perpetuate as great a diversity of tolerant hardwood ecosites as possible.

Development stage is also an important factor influencing use of the tolerant hardwood forest by some species. Of the wildlife that use tolerant hardwood ecosites, around 20 per cent are found only in immature forest (pre-sapling to polewood development stages) and about 10 per cent are found only in mature forest (TABLE 10.1.1). However, generally less than 10 per cent of the wildlife that only use immature forest prefer tolerant hardwood ecosites (i.e. most species that need immature forest prefer other forest or habitat types). In contrast, about 90 per cent of the species that only use mature forest prefer tolerant hardwood ecosites. Thus, managers should attempt to maintain a diversity of development stages within the tolerant hardwood 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 red-shouldered hawks) but there is no simple answer when all species are considered.

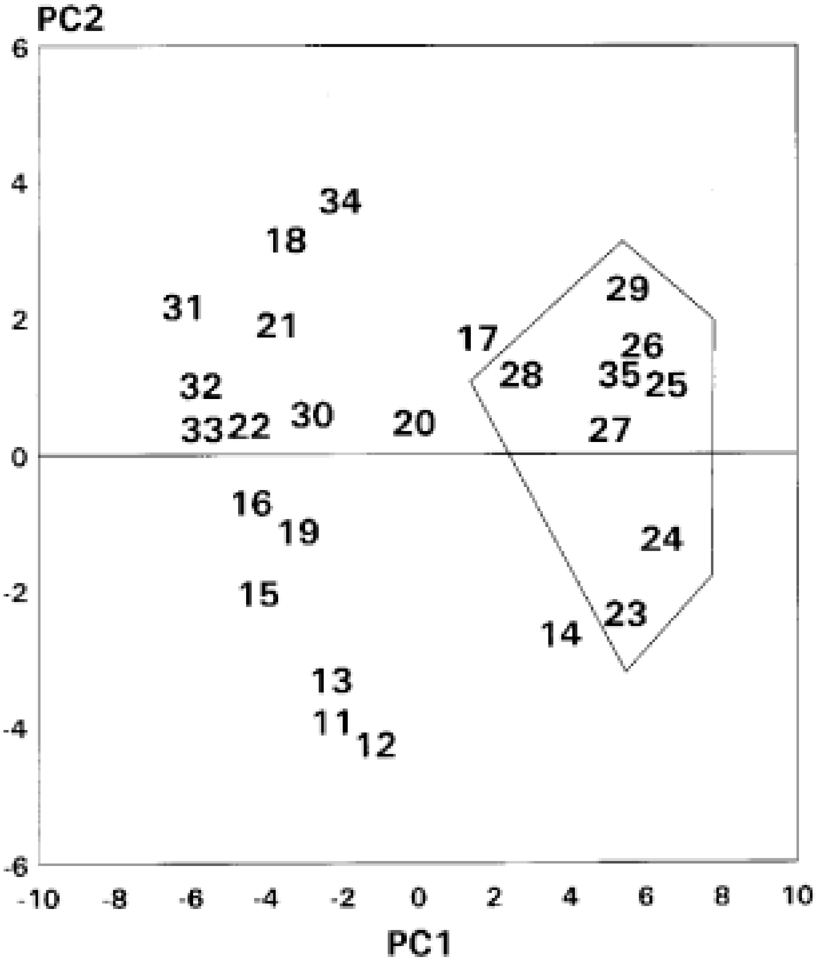
TABLE 10.1.1: Number of species of amphibians, reptiles, birds and mammals using tolerant hardwood ecosites in central Ontario and various habitat components within these ecosites (*based on:* Bellhouse and Naylor 1997).								
Ecosite	Total No. of Species[1]	Immature Forest[2]	Mature Forest[3]	Cavity Users	DWD Users	Mast Users	Conifer Users	Riparian Users
ES 23	149 (67)	36 (2)	16 (14)	37	60	36	15	52
ES 24	142 (67)	32 (2)	15 (14)	37	61	36	10	55
ES 25	156 (72)	35 (3)	16 (14)	39	68	39	16	60
ES 26	157 (73)	35 (3)	16 (14)	39	69	40	17	60
ES 27	157 (73)	35 (3)	17 (15)	42	67	38	16	59
ES 28	150 (62)	26 (1)	14 (12)	41	67	39	22	60
ES 29	153 (72)	35 (3)	15 (13)	40	69	38	14	60
ES 35	144 (70)	31 (3)	13 (12)	36	64	36	13	63

[1] Number of species for which ecosite is preferred habitat in brackets. Note: there is considerable overlap in the species using each ecosite.

[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.

FIGURE 10.1.1: Ordination of central Ontario ecosites based on principal components analysis of wildlife communities described by Bellhouse and Naylor (1997). Numbers refer to ecosite types. The polygon encloses tolerant hardwood ecosites discussed in this section. PC1/PC2 represent ecosite loadings on the first 2 principal components (explaining 49 per cent of the total variance)

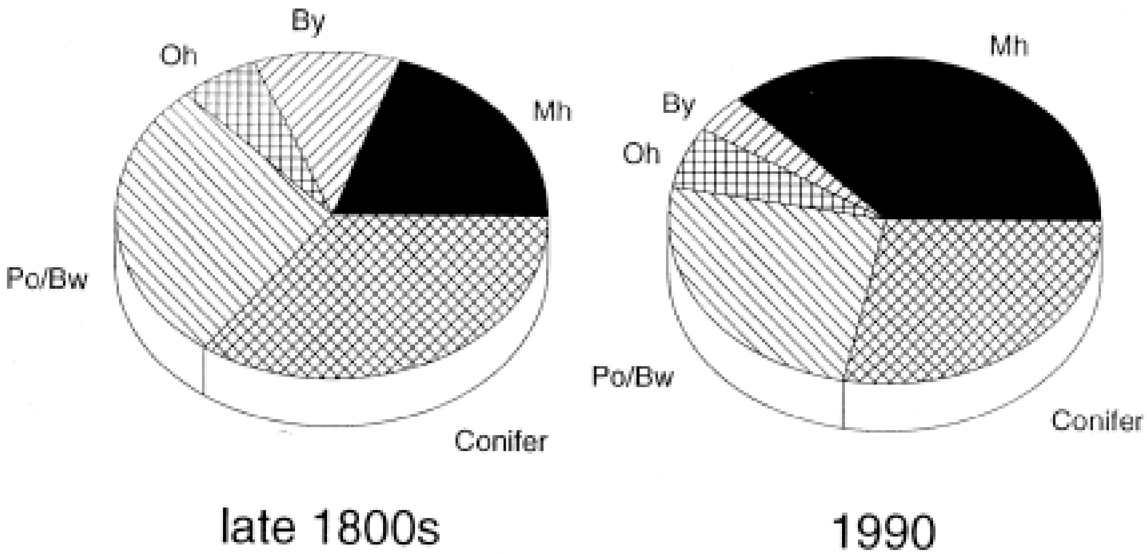


However, it is reasonable to assume that the landscape scale needs of most wildlife will be satisfied if forest management can maintain, within practical bounds, a landscape with roughly the same mix of forest types and age classes (in appropriate patterns) that occurred in the "natural" presettlement 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.

Information about the mix of ecosites found 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 1863-1890) suggests that the area of hard maple-

FIGURE 10.1.2: Comparison of the area of hard maple (Mh), yellow birch (By), other hardwood (OH), intolerant hardwood (Po/Bw) and conifer 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 *unpublished data*). Composition in 1990 is from the Ontario Forest Resources Inventory



dominated forest within these townships has increased substantially during the past 100+ years, largely at the expense of yellow birch-dominated forest (FIGURE 10.1.2).

This small sample cannot be extrapolated to the entire Great Lakes-St. Lawrence forest. 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 10.1.2 should try to adjust management activities to: 1) at least perpetuate the remaining yellow birch-dominated forest and, 2) where feasible, increase the amount of yellow birch in maple-dominated forest where it is or could have been a major component (i.e. ES 28 and ES 29).

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 tolerant hardwood forest of the Great Lakes-St. Lawrence forest region, both catastrophic wind events and wildfire appear to have been stand-replacing agents. In mesic tolerant hardwood forests dominated by species such as hard maple, yellow birch and hemlock, the disturbance cycle for stand-replacing wind events (severe thunderstorm downdrafts, hurricanes and tornadoes) has been reported as 1,210 years in Wisconsin (Canham and Loucks 1984), 1,220 to 2,439 years in lower Michigan (Whitney 1986) and 1,183 to 1,920 years in upper Michigan (Frelich and Lorimer 1991). The disturbance cycle for stand-replacing fires has been estimated at 2,797 years in upper Michigan (Frelich and Lorimer 1991) and 1,389 to 2,778 years in lower Michigan (Whitney 1986). Whitney (1986) suggested a combined wind/fire cycle of 648 to 1,295 years and Frelich and Lorimer's (1991) data suggest a combined cycle of about 998 years.

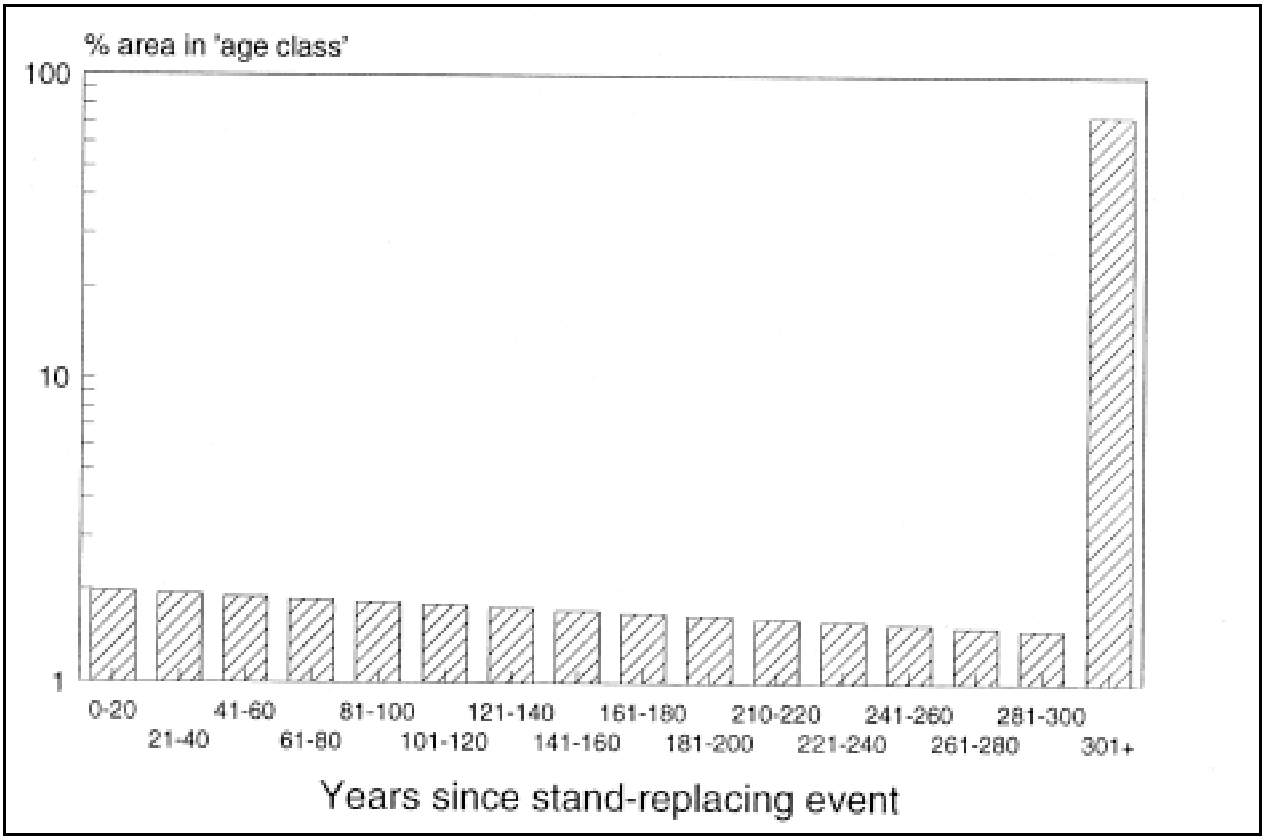
Using a combined wind/fire cycle of 1,000 years, the age class distribution predicted by the negative exponential model is very flat (FIGURE 10.1.3). The x-axis in FIGURE 10.1.3 represents time since the last stand-replacing disturbance. The right-hand tail of the distribution stretches to infinity because some small portion of the forest would theoretically never be affected by wind or fire. At some point along the x-axis, stands will convert from an even-aged to an uneven-aged condition (Borman and Likens 1979). Up to this point, time since disturbance is roughly analogous to stand age (i.e. age of the dominant/codominant tree layer). However, beyond this point, stand age will not necessarily be a good predictor of time since disturbance.

The information generated by this type of modeling can be used to help set some general targets for age class structure in the tolerant hardwood forest. For example, FIGURE 10.1.3 suggests that about 2 per cent of the mesic tolerant hardwood forest would have occurred in even-aged stands within each 20 year age class. If tolerant hardwood forest converts to an uneven-aged condition around 200 years (***see*** Canham and Loucks 1984), a manager might strive to create a landscape with about 20 per cent of the mesic tolerant hardwood forest in even-aged stands ranging from 0 to about 200 years of age. This 20 per cent would be comprised of even-aged stands created by a mixture of natural and managed disturbances. The remainder of the tolerant hardwood forest could be managed using the selection system to maintain stands in an uneven-aged condition.

Xeric sites supporting mid-tolerant hardwoods such as red oak (ES 23) appear to have had a much different disturbance regime. For example, in Michigan, fire cycles (172 to 344 years) and wind cycles (14,286 to 28,571 years) in oak forest were more similar to pine-dominated than tolerant hardwood-dominated forest (Whitney 1986). Given the similarity to pine and the relatively small area of oak forest in most MUs (the assumptions of most disturbance models are more nearly approached when large landbases are used), oak and pine ecosites should be combined when age class modeling is conducted (***see*** Section 8.0 "Integrating Timber and Wildlife Habitat Management" in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*).

When using disturbance models such as that proposed by Van Wagner (1978), 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.

FIGURE 10.1.3: Theoretical age class distribution predicted for the mesic tolerant hardwood forest based on the negative exponential model (combined wind/fire cycle of 1,000 years). Data shown for first 200 years (***see*** text)



The area of different ecosites and age classes on a landscape under a natural disturbance regime can also be estimated through simulation modeling. 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. red-shouldered hawk, pileated woodpecker), others do best with small patches and considerable edge (e.g. ruffed grouse, American woodcock) and others need a complex mosaic of forest types and ages within their home ranges (e.g. moose, white-tailed deer). 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 Environmental Guidelines (OMNR *in prep*.), although these guidelines were primarily designed for boreal-type forests. Managers should use any local information available to help set targets (e.g. analysis of aerial photographs of recent blowdowns or wildfires in the tolerant hardwood 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 tolerant hardwood forests 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 support 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 tolerant hardwoods would not be inconsistent with the pattern of natural disturbance.

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.

There is very little information on other characteristics of blowdowns or on any characteristics of wildfires in the tolerant hardwood forest. Some indication of patch size distribution and dispersion may be obtained from simulation modeling using ONFIRE (Li *et al.* 1996). (For information on disturbance patterns in pine and oak-dominated forest ***see*** Section 8.0 “Integrating Timber and Wildlife Habitat Management” in *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*).

How large should operating areas using single-tree or group selection systems be? This is a difficult question to answer. Selection cutting tends to emulate the fine-scale wind events that occur in the tolerant hardwood forest, create tree-fall gaps of one or a few trees and promote gap-phase replacement (Borman and Likens 1979; Runkle 1981). (*note*: fine-scale wind events may be less prevalent in managed stands since canopy turnover rate is directly related to tree size, ***see*** Dahir and Lorimer 1996).

However, selection cutting and fine-scale wind events differ in their spatial and temporal context. Within a given year, wind events potentially create some gaps in every stand across the landscape; selection harvest concentrates these events into a limited number of stands. Within a given stand, wind events could occur every year; selection cutting compresses all these events into one season. Thus, fine-scale wind events probably promote a relatively homogeneous canopy cover across the landscape while selection management creates more contrast among stands or blocks of stands. This pattern created by selection management could influence the abundance or distribution of species that are sensitive to changes in canopy closure such as red-shouldered hawks (Szuba *et al.* 1992a). This concern is addressed through habitat management for this species (***see*** Section 10.2.5 “Eagles, Ospreys, Herons and Forest-nesting Raptors”).

Dispersion of operating areas is another important factor affecting how wildlife respond to habitat at a landscape scale. Unfortunately, there is little information on the dispersion of patches of natural disturbance in the tolerant hardwood forest. Where effects on individual wildlife species have been documented, they are discussed below (***see*** Section 10.2 “The Fine Filter”).

10.1.2 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 tolerant hardwood forest are: tree species diversity (including mast trees and conifer cover), canopy structural diversity, cavity trees, downed woody debris and supercanopy trees.

TREE SPECIES DIVERSITY

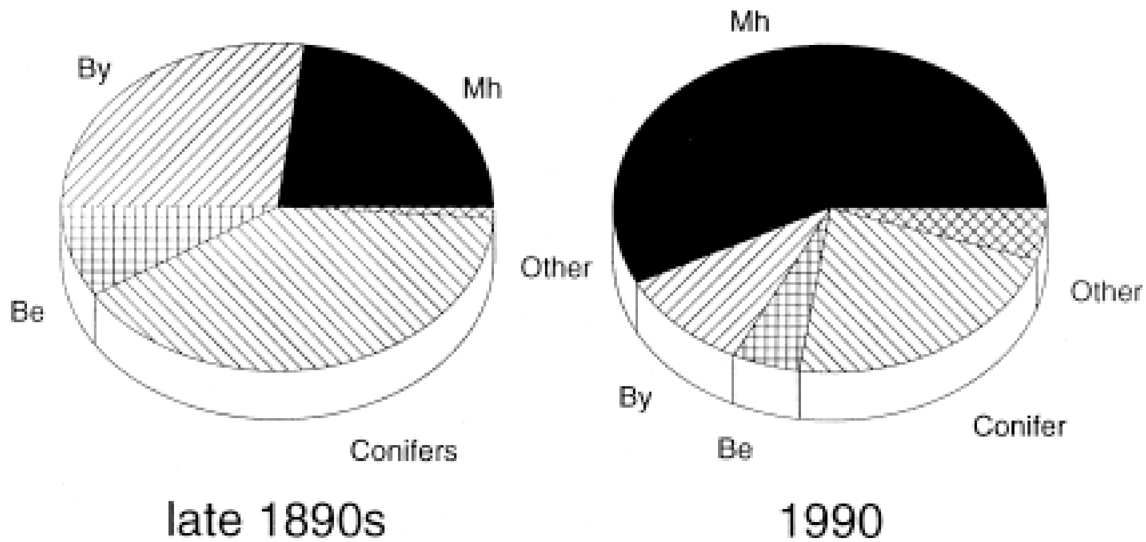
The number of wildlife species using a stand is generally related to the diversity of trees in the overstory (Menard *et al.* 1982). Managers should strive to maintain and perpetuate a mix of species within each stand through time that reflects the site conditions, the prevailing species association and the stand dynamics. Thus, management objectives for each stand should address targets for species diversity in both 1) the residual overstory and 2) the future overstory.

While targets for the composition of the future overstory will incorporate socioeconomic considerations, they should also be based on sound ecological rationale. This should include a consideration of the biological suitability of each species (***see*** Section 4.0 “Silvics”) and also information on the historic diversity of the forest. For example, further analysis of the Crown land survey records for the townships described in FIGURE 10.1.2 suggests that the composition of maple-dominated forest has changed dramatically during the past 100+ years (FIGURE 10.1.4). The relative abundance of maple has increased at the expense of yellow birch and conifers. A manager faced with this kind of information should strive to implement management activities that will at least maintain (if not increase) the amount of birch and conifer in maple-dominated ecosites. This might involve prescribing use of group selection when appropriate to favour yellow birch and special consideration for conifer cover (***see*** “CONIFER COVER” below).

In some cases there may be a strong ecological rationale to reduce the overstory diversity of stands. For example, converting a mixed maple-yellow birch stand to a relatively pure yellow birch stand would reduce diversity at the stand level but would likely be acceptable given diversity considerations at the landscape level.

Diversity of the residual stand will be at least partly dictated by composition objectives for the future stand (e.g. regenerating oak in a mixed maple-oak stand will likely require a large increase in the proportion of oak in the residual overstory). However, within the bounds imposed by the future objectives (including tree species diversity) and the stand’s natural dynamics, the diversity of the residual stand should, as closely as possible, reflect the diversity of the stand before a cut.

FIGURE 10.1.4: Relative basal area of hard maple (Mh), yellow birch (By), American beech (Be), conifers and other species in the late 1800s and in 1990 in maple-dominated forest for the area described in FIGURE 10.1.2. 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



While all tree species contribute to stand diversity, two groups of tree species (mast trees, conifers) have special importance to wildlife and are discussed in more detail below.

About 25 per cent of the wildlife that inhabit tolerant hardwood forest consume edible fruits (mast) produced by trees (TABLE 10.1.1). 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).

MAST TREES

Oaks, American beech, black cherry, basswood, butternut, hickories and ironwood are all important mast-producing trees in the tolerant hardwood forest (Tubbs *et al.* 1987). When stands contain mast trees, current guidelines (*adapted from:* Anderson and Rice 1993) recommend:

- retention of a minimum of 7 to 8 good mast producers per hectare on all ecosites
- retention of species in the following order of priority: hickories, butternut, 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.

When selecting beech trees for retention, evidence of bear claw marks on the bark may indicate a consistent mast producer, especially if there are many sets of marks of varying age. However, bears will damage the crowns of beeches and cherries while feeding (creating “bear nests”). Trees which exhibit damage to a large portion of their crowns are not good candidates for retention.

Some tolerant hardwood ecosites are dominated by mast-producing trees. For example, beech and/or red oak may dominate ES 23 to 25. These ecosites may be extremely important mast-producing areas for wildlife, especially for deer and black bears. Thus, these ecosites should be managed to maintain or enhance short term mast production capability, as well as to perpetuate long term potential, especially when within 2 km of a deer yard (Voigt 1992a) or if there is high evidence of wildlife use (e.g. a beech ridge with many bear nests and an abundance of bear claw marks on tree boles).

CONIFER COVER

About 10 per cent of the wildlife that inhabit tolerant hardwood ecosites use coniferous trees as cover (TABLE 10.1.1). Hardwood stands with dense pockets of conifer (especially ES 28) may be critical components of the habitat of species such as moose, deer and American martens (***see*** Section 10.2.1 “White-tailed Deer”, Section 10.2.2 “Moose” and Section 10.2.4 “American Marten”). Since the average amount of conifer cover in the tolerant hardwood forest in some parts of central Ontario may have declined during the past century (FIGURE 10.1.4), the existing conifer component should be maintained (and perpetuated) where feasible. Pockets of conifer > 0.04 ha in size (20 m x 20 m) should be managed as if they were conifer stands; appropriate silviculture should be applied to perpetuate the conifer species on these sites (***see*** *A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*).

Even scattered conifers can represent important habitat for a variety of species in the tolerant hardwood forest (DeGraaf 1987). A recent study in 30 blocks of tolerant hardwood forest in Algonquin Park suggests that the density of large (40+ cm DBH) conifers has a strong influence on the abundance of songbirds such as the black-throated green warbler and the blackburnian warbler and on overall songbird diversity (FIGURE 10.1.5).

Songbirds appear to be relatively insensitive to changes in the density of conifers when there are more than about 10 conifers per hectare. However, as the density of conifers drops below 10 per hectare, abundance/diversity begins to decline noticeably and drops precipitously when there are fewer than 5 conifers per hectare. This research suggests the following guidelines for the retention of scattered conifers:

- when there are 10 or fewer large conifers/ha ($\leq$ 2 m^2 BA/ha), retain at least 5 conifers/ha and treat the remaining conifers as AGS hardwoods (i.e. remove conifers only when they compete with very high quality hardwoods)

- when there are > 10 large conifers/ha ($\geq$ 2 m^2 BA/ha), retain at least 10 conifers/ha and retain or remove the remaining conifers to meet silvicultural objectives

- retain trees 40+ cm DBH (smaller trees [> 25 cm DBH] may be left when there is a shortage of large trees)

- retain long-lived species such as hemlock, red spruce, white pine or white spruce

- retain individual trees with high vigour and low risk (unless a low vigour tree will contribute to cavity tree objectives)

- trees in clumps (3 or more) may be more valuable than solitary trees

- solitary trees within sight of large conifer pockets are likely less valuable than solitary trees isolated in a sea of hardwoods (except in deer yards—***see*** Section 10.2.1 “White-tailed Deer”).

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 management generally produces stands with high vertical diversity. Vertical diversity can be further enhanced by following guidelines for the retention of supercanopy trees (***see*** “SUPERCANOPY TREES” below). Vertical diversity can be enhanced in clearcuts and shelterwood removal cuts by retaining cavity trees (***see*** “CAVITY TREES” below), supercanopy trees and standards (***see*** Section 9.3 “Implementation of the Silvicultural Systems”).

Textbook application of silvicultural systems will generally produce stands with relatively low horizontal diversity. Horizontal diversity can be enhanced by:

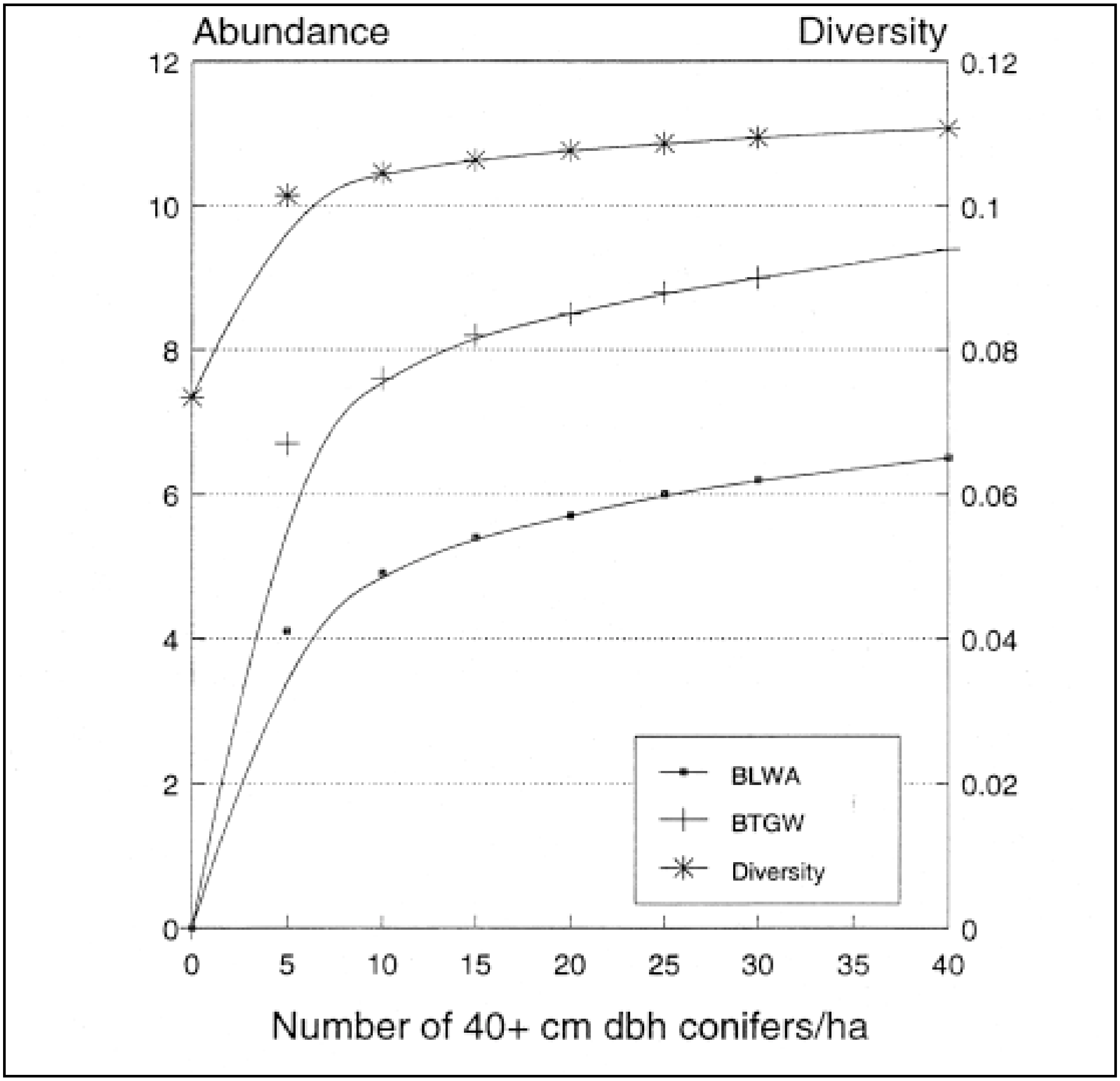
- including some group selection openings in stands managed with the single tree selection system

- leaving some residual trees in clumps in stands receiving a seeding cut in the shelterwood system

- leaving some scattered patches of residual overstory in removal cuts and clearcuts (refer to the *Environmental Guidelines* [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.

FIGURE 10.1.5: Relationship between the abundance of blackburnian warblers (BLWA), black throated-green warblers (BTGW), overall songbird diversity (Simpson's index) and the density of large conifers in tolerant hardwood forest in Algonquin Park



CAVITY TREES

About 25 per cent of the wildlife that inhabit tolerant hardwood ecosites use holes (cavities) in trees for rearing young, roosting, escaping predators, or hibernating (TABLE 10.1.1). 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 tolerant hardwood 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, areas of uncut tolerant hardwood forest had more than twice as many standing dead trees per hectare and more than twice as many living trees with nest or roost cavities as stands that had been selection cut within the past 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 harvest blocks in the tolerant hardwood forest (Naylor *et al.* 1996). In selection cuts 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, a mix of trees with existing cavities and with the potential to develop cavities is suggested. For trees with cavities, priority for retention is: trees with 1) woodpecker nest or natural den cavities, 2) escape cavities and 3) feeding cavities.

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 or shelterwood preparatory and 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 typically 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 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 is at the discretion of the forest worker.

DOWNED WOODY DEBRIS

Between 40 and 45 per cent of the wildlife that inhabit tolerant hardwood ecosites use logs, branches, or stumps on the forest floor (TABLE 10.1.1). 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 DWD has been linked to habitat use by pileated woodpeckers (Renken and Wiggers 1989) and American martens (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, selection management appears to have a minimal negative impact on the supply of DWD. For example, in Algonquin Park, stands with 1 to 20-year old selection cuts had as much or more DWD as uncut stands, even when size and decay condition were considered (Kirk and Naylor *in prep.*). Although selection 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 removal.

However, since the long term impact of forest management on the supply of DWD in the tolerant hardwood 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

- consider 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 tolerant hardwood 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 10.2.2). In upland forest, Naylor (1994a) recommends the retention of at least one supercanopy tree per 4 hectares to provide refuge trees and bedding sites for black bears.

10.1.3 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 the tolerant hardwood forest (TABLE 10.1.1). 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.* 1997).

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.* 1997). 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 or poor quality tolerant hardwoods (ES 27 probably has 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 provide shading and cool water temperatures.

Skidder movement within these sensitive areas can be minimized by requiring operators to avoid seeps and to only cross creeks at a small number of designated points and by requiring them to winch trees out of the riparian areas (Naylor 1994a). In some cases, disturbance may be necessary in these areas to regenerate species such as yellow birch or butternut (***see*** Section 9.4 “Site Preparation”).

10.2 The Fine Filter

Correct application of the coarse filter approach should provide habitat for most wildlife species using the tolerant hardwood forest. However, special consideration may be given to the habitat 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 conifer cover in hardwood stands (coarse filter) benefits deer only if it is located in their yards and if the cover is appropriately dispersed (fine filter) (***see*** Section 10.2.1 “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 tolerant hardwood 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 harvest 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 areas should be dispersed to meet shorter term, spatially explicit habitat supply objectives (e.g. Naylor *et al.* 1994).

At the stand scale, silvicultural prescriptions can be modified to protect or enhance habitat suitability for individual species (e.g. maintain high residual basal area to benefit species such as red-shouldered hawks).

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.

10.2.1 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 the summer, deer are dispersed across the landscape and feed on the growing tips, succulent shoots and flowers of shrubs, herbaceous plants and forbs (Voigt 1992a). Summer food supply influences growth rates and fecundity (Voigt 1992a). 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 (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 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 1992a). 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 tolerant hardwood 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 1992b). Any cutting within the tolerant hardwood forest will increase the amount of summer food, but heavy cuts (clearcuts, shelterwood cuts, or heavy selection cuts) produce more forage for a longer period of time (Ripley and Campbell 1960; Crawford 1976; Healy 1987). Generally, clearcuts are the best way to produce good summer forage since many preferred foods are intolerant of shade. Clearcut (or 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 young forest across summer range through time.

Some clearcutting of tolerant hardwood forest to produce summer food could be considered and would be consistent with the coarse filter approach (***see*** Section 10.1 "The Coarse Filter"). Tolerant hardwood forest with a mix of intolerant hardwoods (e.g. ES 27) would be a good candidate for this treatment. However, in most cases other forest types (those dominated by intolerant hardwoods such as ES 17) within the summer range will be better suited to this silvicultural system and should be considered first when trying to increase this habitat component. Moreover, other forest types can likely be managed on a shorter rotation, ensuring a larger proportion of the summer range will be in an early successional stage.

The size and shape of clearcuts should be consistent with overall objectives for landscape diversity (***see*** Section 10.1.1 "Landscape Scale"). However, within these bounds, small patch clearcuts (up to 4 hectares) or strip clearcuts (up to 100 m wide) are best for deer because they provide optimal interspersion of food and cover (Voigt 1992a). Clearcuts should avoid fragmenting large blocks of mature tolerant hardwood 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 10.1.2 "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 yards, dense conifer stands, especially those dominated by hemlock (ES 30), represent excellent winter cover for deer (Euler and Thurston 1977; Broadfoot *et al.* 1994). However, tolerant hardwood stands containing a strong component of hemlock (ES 28) can also provide winter cover (Bellhouse and Naylor 1997). When individual stands are contributing to short-term or long-term objectives for winter cover, all pockets of conifer within these stands at least 0.04 ha in size, at least 10 m tall and with at least 60 per cent conifer canopy closure should be managed to maintain and perpetuate their snow interception and thermal shelter value . Any cutting should follow the guidelines listed below (*modified from*: Voigt 1992a, b):

- focus on the removal of hardwoods except where removal may damage the residual conifer cover
- maintain at least 60 per cent conifer canopy closure in trees at least 10 m tall
- 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.

When these pockets are providing bedding sites, the guidelines above should be modified to maintain 80 per cent conifer canopy closure (Voigt 1992b).

While these guidelines may maintain the current function of winter cover, they are unlikely to regenerate hemlock (and thus ensure future winter cover) in the presence of high deer numbers (***see*** references in Naylor and Thompson 1992). To maintain high quality cover in hemlock pockets, 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 pockets until deer numbers are low or deer distribution within a yard changes (Anderson 1992).

While dense conifer-dominated forest provides excellent winter cover, it generally has less than half the winter browse of hardwood-dominated stands (Broadfoot *et al.* 1994). Thus, browse supply within hardwood-dominated stands usually dictates winter carrying capacity. The quantity of winter browse in hardwood stands can be manipulated by timber harvest. Clearcutting and shelterwood cutting initially produce a large biomass of deer browse (Harlow and Downing 1969; Crawford 1976; Kelty and Nyland 1983). However, once browse grows beyond the reach of deer, even-aged stands produce little browse until canopy gaps begin to form (***see*** pattern in Broadfoot *et al.* 1994) (high deer numbers may prolong the time that browse remains within reach).

An entire deer yard comprised of tolerant hardwood forest managed using an even-aged system on a 100-year rotation would have stands providing from 5 to 60 kg browse/ha with an overall mean of about 17 kg/ha, based on the model by Broadfoot *et al.* (1994). In contrast, selection management produces a lower but relatively even supply of browse through time. An entire deer yard managed with the selection system would contain stands that could produce between 10 and

30 kg browse/ha and a similar overall mean of 20 kg/ha. More importantly, selection harvest maintains cover that permits deer to access browse (***see*** below). Thus, selection may be the most appropriate system to apply in deer yards dominated by tolerant hardwood forest. To maximize benefits to deer, selection cuts should be scheduled to provide a shifting mosaic of recently cut forest across the yard.

In the past, managers of deer yards frequently prescribed heavy selection cuts to generate deer browse. Generally, heavy selection cuts do produce more woody browse during the first 5 years following a cut (Whitlaw *et al.* 1993). However, heavy cuts extend the cutting cycle. As a consequence, heavy and light cuts tend to produce the same amount of browse per year when averaged over the entire cutting cycle (Whitlaw *et al.* 1993). Thus, low residual basal area targets are usually not necessary to achieve goals for browse production.

Some heavy cutting can be beneficial to deer when selection management is employed. For example, in the Loring deer yard, Bellhouse (1993) found that the area of 0.25 ha patch clearcuts ($\leq$ 6 years old) influenced overwinter mortality of deer. Thus, some group selection openings created while applying the single tree selection system will benefit deer. However, these should be created where they will be accessible to deer (i.e. adjacent to conifer cover, ***see*** below) and will be consistent with other silvicultural objectives.

Winter harvest is generally preferable since tops from recently felled trees provide an immediate food source for deer. However, this may not be desirable when site disturbance during the logging operation is needed to promote the establishment of tree species such as yellow birch or hemlock.

While stands in the tolerant hardwood forest can produce much browse for deer, this only benefits deer if they can access the browse. Only browse within 30 m of conifer cover is generally accessible when snow exceeds 50 cm in depth (Voigt 1992a; Broadfoot *et al.* 1994). Thus, the amount and dispersion of conifer within hardwood stands dictates the contribution these stands make to carrying capacity. Thirty per cent conifer canopy closure, if properly dispersed in shelter patches, will generally permit deer to access all the browse available in hardwood stands (Broadfoot *et al.* 1994). To create a network of shelter patches that will permit deer to access food, the following guidelines should be followed:

- aggregations of conifer at least 0.04 ha in size, at least 10 m tall and with at least 60 per cent conifer crown closure should be managed following the guidelines for winter cover listed above

- aggregations of conifers < 0.04 ha in size should be managed to maintain shelter patches of at least 3 to 5 conifers, at least 10 m tall, with interlocking crowns. Ideally, shelter patches should be 10 to 30 m apart and no more than 60 m apart. In order of priority, retain: hemlock, red spruce, cedar, white spruce, white pine and balsam

- solitary conifers at least 10 m tall that appear to link shelter patches should be retained.

For more information on managing deer habitat ***see*** Voigt (1992a, b).

In high numbers, deer can have a dramatic impact on the regeneration of some tolerant hardwood tree species (e.g. Marquis and Brenneman 1981). Thus, managers should consider this impact when establishing realistic population and habitat targets.

10.2.2 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 tolerant hardwood 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 may 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 moose 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 tolerant hardwood 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). Any timber harvest within the tolerant hardwood forest will increase the supply of browse. Both clearcutting and shelterwood cutting produce a high biomass of browse per hectare. Clearcutting initially produces more browse than shelterwood cutting, but the latter generally produces a relatively good supply of browse for a longer period of time (***see*** Kelty and Nyland 1983). In contrast, selection cutting produces less browse per hectare. However, because stands are entered on a more frequent basis, forests managed with the selection system may have a similar carrying capacity as those managed with an even-aged system (***see*** Section 10.2.1 " White-tailed Deer").

Regardless of silvicultural system used, recently cut forest will only produce an abundant supply of browse until shrubs/saplings grow beyond the reach of moose. Thus, scheduling of operating blocks should produce a shifting mosaic of recently cut forest well-dispersed across moose range (***see*** Allen *et al.* 1987; Naylor *et al.* 1992).

When clearcuts or shelterwood cuts are conducted to improve moose range, their size and shape should be consistent with the coarse filter guidelines. However, to maximize value to moose, clearcuts or shelterwood cuts should ideally be 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 hardwoods 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 are the best summer thermal shelter (Allen *et al.* 1987). However, in tolerant hardwood forest, mature stands of lowland hardwoods (ES 35) may also be suitable. If there is less than one stand of lowland conifers or hardwoods per km^2, summer thermal shelter may be limiting (Allen *et al.* 1987) and existing stands should be managed to maintain high canopy closure (80+ per cent).

Mature tolerant hardwood stands with a mixture of conifers (e.g. ES 28) can be an important component of early winter habitat for moose (Bellhouse and Naylor 1997). These stands may receive high use because they provide both abundant browse and thermal shelter. Timber harvest in these stands can increase browse supply (***see*** Section 10.2.1 "White-tailed Deer") but conifer cover must be protected. Coarse filter guidelines for conifer cover (***see*** "CONIFER COVER" in Section 10.1.2 "Stand Scale") will help maintain thermal shelter.

Mature tolerant hardwood forest in ES 28 may also provide late winter habitat for moose if the conifer component is sufficient (Bellhouse and Naylor 1997). If HSA indicates that specific stands should be managed to maintain late winter habitat, the guidelines described for managing winter cover for deer should be followed (***see*** Section 10.2.1"White-tailed Deer").

Site-specific components of moose habitat may also be encountered in the tolerant hardwood forest and should be managed through AOC planning. Stands of tolerant hardwoods 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 and well-distributed [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 tolerant hardwood 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 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 10.2.1). 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.

TABLE 10.2.1: 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

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 tolerant hardwood 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 of the surrounding landscape for cow moose.

For more information on managing moose habitat ***see*** OMNR (1988a) and Jackson *et al.* (1991).

10.2.3 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 mature tolerant hardwood forest types that contain a component of intolerant hardwoods (ES 23 and 27) (Bellhouse and Naylor 1997). Selection cuts and shelterwood preparatory and seeding cuts do not appear to greatly affect habitat suitability (Kirk and Naylor *in prep*.). However, clearcuts or shelterwood removal cuts produce habitat that will not be preferred again for nesting for 60 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 tolerant hardwood forest must be viewed within the context of changes in overall habitat supply, considering all forest types in the management unit.

Cavity trees, snags and DWD are important components of pileated woodpecker habitat, providing nest, roost, and/or feeding sites (Kirk and Naylor 1996). These essential features of habitat should be provided when the stand level coarse filter guidelines are applied (***see*** "CAVITY TREES" and "DOWNED WOODY DEBRIS" in Section 10.1.2 "Stand Scale").

For more information on managing habitat for pileated woodpeckers ***see*** Kirk and Naylor (1996) and Naylor *et al.* (1996).

10.2.4 American Marten

The American marten is a featured species within the boreal and northern (transition) portions of the Great Lakes-St. Lawrence forest. Mature tolerant hardwood forest with a substantial hemlock component (ES 28) is a preferred habitat (Bellhouse and Naylor 1997). Partial cuts that maintain at least 40 to 50 per cent canopy closure will generally not affect habitat suitability (Watt *et al.* 1996).

Thus, selection or shelterwood seeding cuts in ES 28 should not reduce habitat suitability if existing conifer cover is protected (***see*** "CONIFER COVER" in Section 10.1.2 "Stand Scale"). Clearcuts and shelterwood removal cuts will create habitat that is generally unsuitable for martens until the regenerating stand reaches the polewood development 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 each core area in suitable habitat. Changes in the area of suitable tolerant hardwood forest must be viewed within the context of changes in overall habitat supply, considering all forest types.

Cavity trees, snags and DWD 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 10.1.2 "Stand Scale").

For more information on managing habitat for martens ***see*** Watt *et al.* (1996).

10.2.5 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 tolerant hardwood forest. One or more tolerant hardwood ecosites represent preferred 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 10.2.2).

Four other species of forest-nesting hawks and 3 species of owls also 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 an active nest 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 cuts and shelterwood preparatory and 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 tolerant hardwood 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).

TABLE 10.2.2: 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	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 10.2.2: 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	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 reserve[3] 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[6]	April 1 to August 15	Bowman & Siderius 1984 Agro & Naylor 1994

TABLE 10.2.2: 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	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 10.2.2: 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	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 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[7]	Naylor 1994a
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)

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. For example, red-shouldered hawks require relatively large patches of dense mature tolerant hardwood forest in close proximity to wetlands and lakes but distant from human activity. The coarse filter approach alone may not address these complex spatial requirements. Consequently, HSAs have been conducted for red-shouldered hawks during forest management planning in the southern portion of the Great Lakes-St. Lawrence forest using spatial habitat suitability models (Szuba *et al.* 1992b; Naylor *et al.* 1994). Maintenance of habitat for red-shouldered hawks through time should also ensure that selection management does not cause undo fine scale fragmentation of the tolerant hardwood forest (***see*** "LANDSCAPE PATTERN" in Section 10.1.1 "Landscape Scale").

11.0 HARVESTING CONSIDERATIONS

11.0 Harvesting Considerations

by Harvey Anderson, Brian Batchelor, Wm. Rose and Carl Corbett

Most harvest operations in the tolerant hardwood forest are implemented by conventional cut and skid crews (e.g. one or two cutters working with a skidder). Mechanized logging (mechanical harvesters working with a skidder) accounts for a small percentage of the tolerant hardwood harvest in Ontario.

When harvesting under partial cutting systems like selection and shelterwood, some degree of physical damage to residual stems and regeneration is inevitable. Damage to the site is a concern in any silvicultural system, with damage severity dependent on ecosite and/or weather conditions. Minimizing the amount of damage is a critical factor in achieving tolerant hardwood management objectives.

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 tolerant hardwood forest. Specific guidance related to operations affecting the aquatic environment is provided in "*Timber management guidelines for the protection of fish habitat*" (OMNR 1988b), "*Environmental guidelines for access roads and water crossings*" (OMNR 1988c) and "*Code of practice for timber management operations in riparian areas*" (OMNR 1991).

This section deals with the management implications of logging damage, emphasizing the consequences of damage to the stems and root systems of residual trees, the varying potential risk for damage by ecosite and "careful logging practices" that can minimize damage. Much of this information was derived from papers by Anderson (1994), Dey (1994) and Nyland (1994) in *Forest Research Information Paper No. 117 - Logging Damage: The Problems and Practical Solutions*.

11.1 Management Implications

The success of the selection and shelterwood silvicultural systems is dependent upon the survival and growth of the residual trees and regeneration. It is therefore extremely important that a harvesting operation leave as many stems as possible undamaged and the site in a productive state.

The types of injury and damage that may be encountered 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 (erosion, rutting).

Injury categories that are considered to be major are identified in TABLE 11.1.1. Specific indicators of a variety of biotic and abiotic defect sources are outlined in Anderson and Rice (1994).

TABLE 11.1.1: Common injuries to trees during logging operations in northern hardwoods (*modified and adapted from*: Nyland and Gabriel [1971])

TYPE OF INJURY	CONSIDERED MAJOR WHEN...
Bark scraped off	**Trees 10 to 31 cm DBH** Any wound greater than or equal to the square of the DBH (e.g. for a 10 cm DBH tree, a major wound is greater than 100 cm^2)
	Trees 32+ cm DBH Any wound greater than 1,000 cm^2
	Note: *Wounds on yellow birch (or ground contact wounds on other species) are considered to be major at 60% the size shown above for all size classes. (e.g. 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 crown is destroyed
Root damage	More than 25% of the root area exposed or severed
Broken off	Any tree
Bent over	Any tree tipped noticeably

11.1.1 Bole wounds caused by bark scraping or peeling

Bole wounds are a concern since hardwood timber value is directly related to the occurrence of clear, unblemished wood in straight, round logs and is significantly decreased by the incidence of defects such as stain and rot. Premiums are often paid for sugar maple logs with a high proportion of “white wood”. This white wood is produced when a tree has grown unhindered for some time without serious tissue injury or breakage.

The amount of defect (stain and rot) associated with logging wounds increases with the original wound surface area and the length of time since wounding. Nyland (1994) linked size of wound to increased incidence of decay (wounds greater than 1,000 cm^2 displaying a 50 per cent chance of developing measurable defect within a 20 to 25 year period) and Anderson (1994) concluded that rot accounted for about 10 per cent of the total internal tree defect. Other studies have shown similar relationships (Hesterberg 1957; Shigo 1966). Once the wounds have overgrown, the volume of rot may become relatively constant, (i.e. not increase), assuming no further injury.

Wound reopening due to the action of frost is thus a serious concern at the northern fringes of a species' range.

Wound size and placement are clearly critical in the determination of subsequent stain and decay development. Wounds that contact soil generally result in greater amounts of decay because the wound surface remains moist and therefore provides a better environment for infection (Dey 1994). This information has been used in the determination of what constitutes "major" bark abrasion damage shown in TABLE 11.1.1.

The potential for bark wounding varies throughout the year. Trees are much more vulnerable to injury in the spring when they are actively growing. During this period, the cells are thin-walled and flexible and the cambial layer is especially susceptible to damage and will fragment when impacted. This results in bark slippage and eventual scar formation. As reported by Wilcox *et al.* (1954), sugar maple bark strength is very high while the tree is dormant in the fall and winter but begins to decrease in April and is weakest in May. Bark strength remains low until approximately the end of July when it again rises to an acceptable level.

11.1.2 Root breakage

As reported by Dey (1994) root injuries occur 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.

Damage to the root system can interfere with nutrient and moisture absorption thereby reducing the vigour of residual trees. If a large amount 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, however, is the creation of potential entry courts for infection by root-rot fungi like *Armillaria* spp. and sapstreak disease (*Ceratocystis coerulescens*), both of which are potentially fatal. Root wounds are also a major cause of defect in the butt log (Dey 1994) reducing the volume and value available in future harvests.

11.1.3 Crown damage resulting from branch breakage

Broken branches greater than 8 cm in diameter may pose a decay hazard (Hesterberg 1957) and have a 50 per cent chance of developing measurable defect within a 20 to 25 year period (Nyland 1994).

Damage that creates “frayed” stubs are of greater concern. Such stubs are ideal infection courts because of their fragmented nature and their affinity to trap and retain moisture when in an upright position.

Damage in the crown is also a concern due to the loss of photosynthetic potential and the subsequent reduction in tree vigour which can have an affect on tree growth. This will not only reduce the volume available in future harvest from individual trees, but the reduced growth could also affect future diameter distribution in the stand which will have an impact on allowable harvest.

11.1.4 Stem breakage/bending or tilting of trees

Stem breakage, bending, or tilting occurs in all size classes but has it's greatest impact on the pole size class and on regeneration.

Nyland (1994) reports that the frequency of injuries within a 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. Nyland *et al.* (1976) indicate that, even with reasonably good logging practices, approximately 15 per cent of trees less than 10 to 13 cm DBH will be lost. This is of special concern in selection management where the goal is to create and maintain an uneven-aged stand structure in which there are comparatively more trees in the smaller size classes.

11.1.5 Soil/site damage

In addition to impacts on residual trees and regeneration, damage to the site can result from 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.

TABLE 11.0.2, TABLE 11.0.3 and TABLE 11.0.4 as reported by Archibald *et al.* (1997 *in press*) show the relative site damage hazard from compaction, rutting, erosion and nutrient loss for the 27 soil types in the central Ontario FEC classification system. 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.

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

- **Percent 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.

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 *in press*) are as follows:

- they create an opportunity for water ponding which will reduce the productive area of the site

- they physically compact the soil on the sides and base of the rut which inhibits water infiltration, rooting and gas exchange

- they impede the lateral drainage of water on the site

- they 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

- **Percent 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 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.

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 can:

- reduce site productivity through the physical removal of the nutrient-rich upper soil layers. In extreme cases this can result in some sites being unproductive (e.g. exposed bedrock, steep gullies, sterile exposed mineral soil, smothering of productive soil profiles by sterile soils)

- degrade water quality and/or fish habitat by depositing soil particles and nutrients into water bodies

- damage or destroy 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

- **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 11.0.2: A general rutting and compaction hazard potential rating by soil type (*adapted from*: Archibald *et. al* 1997 *in press*)

RUTTING AND COMPACTION HAZARD RATING

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

TABLE 11.0.3: A general erosion hazard potential rating by soil type (*adapted from*: Archibald *et al.* 1997 *in press*)

EROSION HAZARD RATING

SOIL DESCRIPTION			FEC/ELC SOIL TYPE			SITE DAMAGE HAZARD		
texture	depth mineral	depth organic	Northwest	Northeast	Central	slope 0 - 10%	slope 11 - 30%	slope >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		

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 selection and shelterwood systems, result in a significant loss of nutrients that will affect forest productivity (Clements 1973).

The forest floor is important for the biochemistry and ecology of the 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 cutovers 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 11.0.4: A general nutrient loss hazard potential rating by soil type (*adapted from*: Archibald *et al.* 1997 *in press*)								
NUTRIENT REMOVAL HAZARD RATING								
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

11.2 Careful Logging Practices

Careful logging is the harvesting of timber products in a manner that avoids injury to forest workers while minimizing damage to residual trees, advanced reproduction 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 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 on through to the planning of operations on an individual cut block.

The Forest Management Plan should stress the importance of minimizing damage to the 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 identified sites at times of high damage potential for excessive logging damage, or to be ready for potential problems during periods of unfavourable weather.

For example, some jurisdictions plan their harvest so as to avoid working in tolerant hardwood stands in the spring when the hardwoods are most susceptible to bark damage and soil moisture levels tend to be high. An alternative is to establish clear objectives and standards that would apply regardless of time of year and or soil condition. Forest managers may then modify or postpone operations under identified 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 those responsible for wood procurement so that problems with wood supply to the mills can be dealt with early in the planning process. If the mill requires a certain product mix, this has to be understood and operations scheduled to avoid delivery problems while 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 for the cut block. They may then plan the harvest to ensure a safe and effective cut progression, optimizing production and minimizing logging damage.

It is at this stage that the training, experience and silvicultural knowledge of the harvesting crew is important. Safe/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. Skidder assistance is often required to safely drop such trees. This costs the operator time and money and the 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 cutting crews to choose where the damage will occur. A careful operator can often choose to damage a stem marked for removal, or a tree which is unacceptable growing stock (UGS), while protecting desired regeneration and acceptable growing stock (AGS) which has been selected for retention.

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 who 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 UGS

- using the main-line and winch to reduce the amount of travel necessary by the skidder.

Communication between the forest manager and the harvesting crew is critical. Nyland (1994) felt that the key element in conducting a successful harvesting operation was developing a rapport with the harvesting contractor. If the forest workers understand the relevant management goals and objectives, they can then take steps necessary to minimize logging damage. The attitude and skill of a logging crew is the most important factor in minimizing logging damage.

12.0 MANAGEMENT STANDARDS

12.0 Management Standards

by Al Corlett, Brian Batchelor and Fred Pinto

Many forest- and stand-level objectives are accomplished through silvicultural activities. Those objectives are identified in the Forest Management Plan and linked to specific measurable standards in the s*ilvicultural ground rules* (***see*** Section 9.1.1 "Silvicultural ground rules" and FMP-10 of the Forest Management Planning Manual). Such standards should reflect areas of critical concern such as forest productivity, long term product goals and forest health. Useful indices are: species composition, stocking, density, quality of the growing stock and physical impacts of management activities on the site, among other factors.

While suggested standards are defined below, it is expected that some variation from the standards or guidelines presented may be necessary at the local level. Ecological rationale for such adjustments must be provided in the relevant Forest Management Plan.

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 will ensure attainment of long-term resource objectives for the site.
- The major product objective for most species of the tolerant hardwood forest will be sawlogs and veneer, with fibre as a by-product except on the poorest site conditions. Product quality as determined by stem straightness, taper, freedom from defect and knot size is especially critical.
- Established standards must recognize a range of actual stand treatment objectives, including silvicultural objectives extending beyond regeneration and ecological objectives which extend beyond basic silviculture.
- The degree to which objectives can be attained will often be affected by site condition. Wherever possible, standards should consider ecosite and be adjusted accordingly.

12.1 Attributes for which Standards are Required

Silvicultural treatments cause changes in individual stands. Collectively, changes at the stand level result in changes to forest composition, structure and function. Consideration of treatment effects on stand development potential, maintenance of biodiversity and the maintenance of productivity is thus required.

12.1.1 Maintenance of stand development potential

REGENERATION CHARACTERISTICS

Regeneration is an objective of all silvicultural systems. As stand renewal is the principal silvicultural objective of the clearcut system, a measure of regeneration development at an established point in time will normally indicate whether stand and thus forest level objectives, are being met. Stand renewal is one of the objectives of partial cut systems such as uniform shelterwood or group selection and will indicate attainment of a portion of the objectives.

A mature, fully stocked stand of tolerant hardwoods can disperse 20 to 25 million seeds per hectare in a good seed year (Benzie l959b). As many as 2.5 million seedlings per hectare may persist for the first year. Survival rates for yellow birch seedlings (as well as others in the tolerant hardwood forest) may be only 40 per cent by year five and 10 per cent by year ten in stands managed by recommended prescriptions, such as group selection. Because of sheer seedfall density, after nine years as many as 198,000 seedlings per hectare can survive, ranging in size from 15 cm tall to 1.27 cm DBH (Tubbs 1977a).

The dynamic nature of the population over time has prompted various researchers to recommend the use of stocking, density, or a combination of both in defining levels of hardwood regeneration capable of meeting long-term stand level objectives. McEwen *et al.* (1958) recommended that “stocked” mil-acre sample plots (equivalent to 4.05 m^2) be required to have ten established seedlings at the end of one growing season and that satisfactory stocking be defined to mean that 80 per cent of quadrats are classified as “stocked”. Tubbs (1977a) recommended a minimum of 12,355 well-spaced seedlings, or 2,471 saplings (5 to 10 cm DBH), per hectare. Marquis *et al.* (1990) recommends 20 small (<4.5 feet tall) or 1 large (>4.5 feet tall) red oak, or 15 black cherry advanced regeneration stems for a 6 foot radius plot (approximately 10.5 m^2) to be considered “stocked” under low deer pressure conditions.

Regionally established *free-to-grow* standards have been used to define benchmark regeneration standards in Ontario. Stocking, height and freedom from competition are the criteria used. Stands managed under the selection system are considered to be in a state of continuous growth and therefore deemed to be *free-to-grow* at all times and have therefore not been covered in these standards. The approach has been applied to areas managed under the uniform shelterwood and clearcut systems, an example of which is shown in TABLE 12.0.1.

In the presence of mixed species or sprout stems and for areas comprising both natural and artificial (planted) regeneration, the *free-to-grow* criteria have been difficult to apply. Smith (1983) found that hard maple mixed with red oak and black cherry developed very poorly despite the fact that it was maintained for 12 years in a *free-to-grow* condition. The approach also fails to take into account the dynamic nature of the developing regeneration.

TABLE 12.0.1: Free-to-grow standards for uniform shelterwood regeneration in Algonquin and Eastern regions					
Forest Unit	Site Class	Free-to-Grow Minimum Stocking	Stocking Objective	Minimum Total Height (m)	Regeneration Period (yrs)
Mh/Oh mix	X,1	>= 80% Mh, Or, By, Bd, Aw, Cb	>=90% Mh, Or, By, Bd, Aw, Cb	1.0	5
Mh/Oh mix	2,3	>= 70% Mh, Or, By, Bd, Aw, Cb	>=80% Mh, Or, By, Bd, Aw, Cb	1.0	5

It is therefore appropriate that future silvicultural ground rules will define benchmark regeneration development standards for tolerant hardwoods in the Great Lakes-St. Lawrence forest using both stocking and density targets to be achieved at a pre-determined stage of development. Minimum seedling density of acceptable species may vary somewhat depending on the characteristics of the species of interest, but is generally recommended to be 12,500 stems per hectare. TABLE 12.0.2 illustrates the information needed in the detailing of minimum standards in future silvicultural ground rules.

TABLE 12.0.2: Example: tolerant hardwood regeneration standards, uniform shelterwood or clearcut silvicultural system							
Forest Unit	Ecosite	Residual Overstory	REGENERATION				
		Acceptable Species (listed in order of priority)	Acceptable Species (listed in order of priority)	Minimum Stocking % - all species in forest unit	Density number of stems/ha	Total Height minimum (m)	Assessment Timing years after treatment
Mh	25.2	Mh, Or, Be, Aw, Pw	Mh, Or, Aw , Be, Pw	80% total Mh 60%	12,500 seedlings per ha or 2,500 saplings per ha	1.8 to 2.4 m (for Or: 1.2 m & basal caliper 1.3 cm)	7 to10

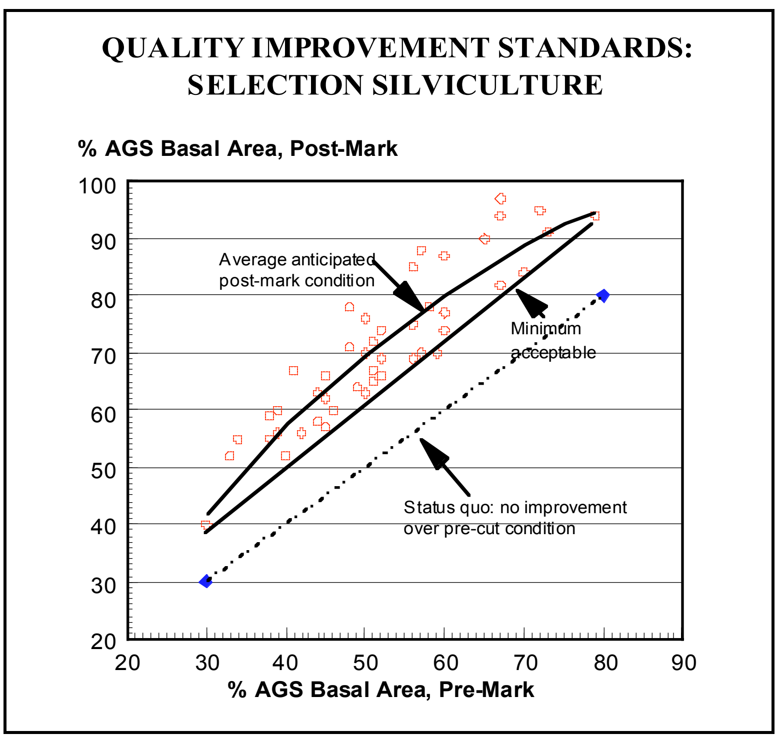
DEVELOPMENT POTENTIAL OF RESIDUAL TREES

Partial cut systems are well-suited to the silvical requirements of the tolerant hardwoods. When implemented effectively, residual stems retained according to the requirements of the uniform shelterwood and more particularly the selection systems will have a significant and very positive impact on wood flow, quality and supply over the subsequent 20 to 60 year term.

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 improvement in proportion of Acceptable Growing Stock is one of the critical indices of the effectiveness of the tree marking program in the regulation of selection silviculture. FIGURE 12.0.1 presents results of acceptable tree marking operations in several districts of the Great Lakes-St. Lawrence forest. The results indicate that quality improvement target levels are dependent on initial stand condition, suggesting targets of 12 to 20 per cent improvement in AGS level and a minimum acceptable improvement standard of 10 to 13 per cent. Anderson and Rice (1996) provides a useful case-study of tree marking quality assurance in Algonquin Park.

FIGURE 12.0.1: Quality improvement standards for tree-marking



Other considerations of the Tree Marking Quality Assessment are:

- residual species composition
- vigour and risk characteristics of residuals
- residual stocking levels which optimize both volume production and the development of regeneration.

Specific details are located in Section 9.3 “Implementation of the Silvicultural Systems”. The assessment procedure is outlined in *Assessment of Silvicultural Systems in the Great Lakes-St. Lawrence Forest Region* (unpublished report) and expressed in more detail in the “Level 2 Tree Marker Licensing Course”. The current standard is that the Tree Marking Quality Assessment, as carried out by an approved assessor, must be greater than 90 per cent to be minimally acceptable. This standard is currently under review and is expected to be raised. Assessments greater than 95 per cent are an indication that all objectives are being met.

12.1.2 Maintenance of biodiversity

While it is essential to take a landscape approach if a region’s entire biota is to be maintained, it is short-sighted to see only the “macro” view (Hunter 1990). Critical elements of a diverse forest such as cavity trees, snags, stick nests and down woody debris are readily apparent only at the stand level. The manager must allow for consideration of the cumulative effects of individual stand level silvicultural activities on forest biodiversity.

To ensure that negative effects on forest sustainability are minimized or prevented, standards that can be used to define and guide the planning and implementation of silvicultural activities must be established.

Forest managers should be aware of the consequences of silvicultural practices on:

- genetic diversity
- stand species composition
- stand structure: physical structure and stand age-class.

An important means to maintaining and restoring genetic diversity is through the choice of trees selected for retention in partial cuts and the tree species given priority for renewal. Other practices and standards for the maintenance and restoration of genetic diversity are described in Section 8.0 “Genetics”.

Stand structural diversity is important for ecosystem function. For example, cavities in trees are used for rearing young, roosting, escaping predators, or hibernating by about 26 per cent of the wildlife that inhabit tolerant hardwood ecosites. Structural diversity standards may be found in Section 10.0 “Habitat Management Considerations”.

The age class of a forest is affected by harvest and renewal activities. Decisions related to stand harvest and renewal must consider the age class that natural disturbances would create. Computer models should be used for this exercise during the preparation of a Forest Management Plan. Harvest and renewal activities should then attempt to emulate the hypothetical natural age-class for the forest. Methods and standards related to the modelling of the hypothetical natural age-class of a forest can be found in Section 10.0 “Habitat Management Considerations”.

When applying systems which require tree-marking, many critical ecological objectives dealt with at the stand level must be considered as an integral part of the tree-markers’ decision-making process and of the Tree Marking Quality Assessment.

12.1.3 Maintenance of productivity

Stand productivity can be affected by the improper application of the correct silvicultural treatment or through the application of the improper treatment. Site visits prior to operations will minimize the chances of either error type occurring. See Section 9.1 “Prescription Development” for suggestions and standards for the development of site specific prescriptions.

Standards of site productivity may be developed using the information found in Section 7.0 “Stand Growth and Yield”. These standards, usually expressed as 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. Section 11.0 “Harvesting Considerations” details the types and consequences of damage that can be incurred by residual trees and the site during management operations. The severity of individual bole wounds, as well as root, crown or stem breakage to an individual tree, at which point such damage is considered major, are also illustrated. Obviously, any entry into the forest will result in damage at some level, however it is important that limits be defined at which the sustainability of the system, or the ability of the stand to continue contributing to forest level objectives, will be affected.

TABLE 12.0.3 illustrates operationally attainable, recommended stand level standards for partial cut systems. They are based on the experience of practitioners and wherever possible, the results of applied 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. These factors are explained in Section 11.0 “Harvesting Considerations” and

Section 9.4 “Site Preparation”. Local site impact guidelines developed by the Algonquin Forestry Authority in conjunction with area operators are shown below. These guidelines were developed specifically for Algonquin Park 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 12.0.3: Stand level standards for partial cut harvesting systems	
DAMAGE TYPE	STANDARD
Damage to residual stems	After harvesting, 85 per cent of the residual basal area (10+ cm) should be free of major damage and 90 per cent 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 and density regeneration standards as detailed in s*ilvicultural ground rules* must be maintained following release operations (i.e. removal cuts of the shelterwood system).
Skid trail coverage	A minimum of 70 per cent of the ground area in uniform shelterwood areas and 80 per cent in selection areas is to be skid trail free.

SITE IMPACT GUIDELINES FOR ALGONQUIN PARK			
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

Literature Cited

Aber, J.D., J.M. Melillo and C.A. Federer. 1982. *Predicting the effects of rotation length, harvest intensity and fertilization on fiber yield from northern hardwood forests in New England*. Forest Science 28: 31-45.

Agro, D.J. and B.J. Naylor. 1994. *Effects of human disturbance on colonies of the great blue heron* (Ardea herodias) *in Ontario*. Draft CRST Technical Report. No. 35. Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON. 17 pp.

Ahrens, W.H. (ed.). 1994. *Herbicide handbook*. 7th edition. Weed Science Society of America. Champaign, IL.

Allen, A.W., P.A. Jordan and J.W. Terrell. 1987. *Habitat suitability index models: moose, Lake Superior region.* Biology Report 82(10.155). U.S. Department of the Interior, Fish & Wildlife Service. 47 pp.

Anderson, E.F. and G.A. McCormack. 1967. *Anchor chain scarifiers in Ontario.* Silvicultural Note No. 2. Toronto: Timber Branch, Ontario Department Lands and Forests.

Anderson, H.W., E.P. Boysen, D.C. Dey and J.A. Rice. (1997 *in press*). *Natural regeneration of hardwoods. In*: Regenerating Ontario's Forests. R.G. Wagner and S.J. Colombo (eds.). Toronto: Fitzhenry and Whiteside.

Anderson, H. W. 1994. *Some implications of logging damage in the tolerant hardwood forests of Ontario*. pp. 3-28. *In*: Logging Damage: The Problems and Practical Solutions. J.A. Rice (ed.). Forest Research Report No. 117. Ontario Ministry of Natural Resources, Ontario Forest Research Institute. Toronto.

Anderson, H.W. 1982. *Regenerating yellow birch with prescribed fire*. pp. 168-172. *In*: Proceedings of Society of American Foresters Convention at Cincinnati, OH. Society of American Foresters Publication No. 83-04. Society of American Foresters. Washington, DC.

Anderson, H.W. 1992. *Hemlock: its ecology and management*. pp. 62-86. *In*: Regenerating Conifer Cover in Deer Central Ontario Forest Technology Development Unit Yards. B. Naylor and L. Thompson (eds.). COFTDU Technical Report No. 28. Ontario Ministry of Natural Resources, Central Ontario Forest Technology Development Unit, North Bay, ON.

Anderson, H.W., B.D. Batchelor, C.M. Corbett, A.S. Corlett, D.T. Deugo, C.F. Husk and W.R. Wilson. 1990. *A silvicultural guide for the tolerant hardwoods working group in Ontario*. Science and Technology Series, Volume 7. Ontario Ministry of Natural Resources, Forest Resources Group. Sault Ste Marie, ON.

Anderson, H.W. and J.A. Rice. 1993. *A tree-marking guide for the tolerant hardwoods working group in Ontario*. Science and Technology Series, Volume 8. Ontario Ministry of Natural Resources, Forest Resources Branch. Sault Ste Marie, ON. 227 pp.

Anderson, H.W. and J.A. Rice. 1996. *Quality assurance in hardwood tree-marking: a case study*. Forest Research Report No. 141. Sault Ste Marie, ON: Ontario Forest Research Institute, Ontario Ministry of Natural Resources. 14 pp.

Anderson, H.W. and M.M. McLean. 1970. *Value increase potential of various grades of sugar maple trees*. Ontario Department Lands and Forests, Research Branch. Dorset, ON.

Anon. 1930. *Form-class volume tables*. Canadian Department of the Interior, Canadian Forest Service. 199 pp.

Anon. 1948. *Form-class volume tables*. Canadian Department Mines and Resources, Dominion Forest Service. 261 pp.

Arbogast, C., Jr. 1957. *Marking guides for northern hardwoods under the selection system.* Station Paper No. 56. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Archibald, D.J., B.W. Wiltshire, D.M. Morris and B.D. Batchelor. *in press. Forest management guidelines for the protection of the physical environment*. Ontario Ministry of Natural Resources, Peterborough, ON.

Arend, J.L. and H.F. Scholz. 1969. *Oak forests of the Lake States and their management.* Research Paper NC-31. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Arnup, R.W., B.J. Dowsley, L.J. Buse and F.W. Bell. 1995. *Field guide to the autecology of selected crop trees and competitor species in northeastern Ontario*. Report No. FG-005. Ontario Ministry of Natural Resources, Northeast Science and Technology. 152 pp.

Ashenden, G.A. 1957. *Final report for 1956-57 scarification project, Staniforth Lumber and Veneer Licence, Kiosk Management Unit*. Ontario Department Lands and Forests. Pembroke, ON.

Auchmoody, L.R. and H.C. Smith. 1993. *Survival of northern red oak acorns after fall burning*. Research Paper NE-678. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Auclair, A. and G. Cottam. 1971. *Dynamics of black cherry* (Prunus serotina) *in southern Wisconsin oak forest*. Ecological Monogram 41: 153-177.

Bankowski, J., D. Dey, E. Boysen, M. Woods and J. Rice. 1996. *Validation of NE-TWIGS for tolerant hardwood stands in Ontario*. Forest Research Information Paper No. 130. Ontario Ministry of Natural Resources, Ontario Forest Research Institute. 21 pp.

Bankowski, J., D. Dey, M. Woods, J. Rice, E. Boysen, B. Batchelor and R. Miller. 1995a. *Validation of Fiber 3.0 for tolerant hardwood stands in Ontario*. Forest Resource Information Paper No. 124. Ontario Ministry of Natural Resources. 32 pp.

Bankowski, J., D. Dey, M. Woods, J. Rice, E. Boysen and R. Miller. 1995b. *Validation of SILVAH for tolerant hardwood stands in Ontario*. Forest Research Information Paper No. 128. Ontario Ministry of Natural Resources, Ontario Forest Research Institute. 28 pp.

Basham, J.T. 1973. *Hardwood management in southern Ontario: how extensive and important are stain and rot in living trees?* Information Report O-X-186. Canadian Forest Service, Great Lakes Forest Research Centre. Sault Ste Marie, ON.

Basham, J.T. 1991. *Stem decay in living trees in Ontario's forests: a users' compendium and guide.* Information Report 0-X-408. Forestry Canada, Ontario Region, Sault Ste Marie, ON. 69 pp. (includes appendicies).

Basham, J.T. and H.W. Anderson. 1977. *Defect development in second growth sugar maple in Ontario*. *In*: Microfloral Infection Relationships Associated with Dead Branches. Canadian Journal of Botany 55: 934-976.

Basham, J.T. and Z.J.R. Morawski. 1964. *Cull studies: the defects and associated basidiomycete fungi in the heartwood of living trees in the forests of Ontario.* Publication No. 1072. Canadian Department of Forestry. Ottawa.

Baxter, D.V. 1943. *Pathology in forest practice.* New York: John Wiley & Sons.

Beattie, M., C. Thompson and L. Levine. 1983. *Working with your woodland: a landowner's guide.* Hanover: University Press of New England.

Belcher, D.M. 1982. *TWIGS: The woodman's ideal growth projection system*. *In*: Microcomputers, A New Tool for Foresters. Purdue University. 70 pp.

Bell, F.W. 1991. *Critical silvics of conifer crop species and selected competitive vegetation in northwestern Ontario*. COFRDA Report No. 3310 / NWOFTDU Technical Report No. 19. Forestry Canada, Ontario Region, Ottawa/Northwest Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources, Thunder Bay, ON. 177 pp.

Bell, F.W., A.J. Willcocks and J. Kavanagh. 1990. *Preliminary variable density yield tables for four Ontario conifers*. NWOFTDU Technical Report No. 50. 80 pp.

Bellhouse, T. 1993. *Impact of management actions on the white-tailed deer population in wildlife management unit 47: 1971-90*. pp. 1-44. *In*: The History and Management of White-tailed Deer in Wildlife Management Unit 47. T. Bellhouse (ed.). CRST Technical Report No. 22. Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON.

Bellhouse, T. and B. Naylor. 1996. *The ecological function of down woody debris in the forests of central Ontario*. CRST Technical Report No. 43. Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON. 29 pp.

Bellhouse, T.J. and B.J. Naylor. 1997. *Habitat relationships of wildlife in central Ontario*. SCST Technical Report No. 53 . Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON. 58 pp.

Bellhouse, T.J. and R. St. Martin. 1996. *Ecosystem approach to managing the white-tailed deer herd wintering at Loring: a discussion paper for consideration in future planning initiatives*. (Unpublished Report). Ontario Ministry of Natural Resources, North Bay District. 53 pp.

Bentley C.V. and F. Pinto. 1994. *Autecology of selected understorey vegetation in central Ontario*. Central Region Science and Technology Technical Report No. 31/Vegetation Management Alternatives Program Technical Report No. 93-08. Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON. 169 pp.

Benzie, J.W. l959b. *Sugar maple and yellow birch seed dispersal from a fully stocked stand of mature northern hardwoods in the Upper Peninsula of Michigan.* Technical Note No. 561. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Berry, A.B. 1981a. *A study in single-tree selection for tolerant hardwoods.* Information Report PI-X-8. Canadian Department of the Environment, Canadian Forest Service.

Berry, A.B. 1981b. *Metric form-class volume tables*. Information Report PI-X-10. Canadian Department of the Environment, Canadian Forest Service. 24 pp.

Berry, F.H. and F.F. Lombard. 1978. *Basidiomycetes associated with decay of living oak trees.* Research Paper NE-413. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Bey, C.F. 1964. *Advance oak reproduction grows fast after clearcutting*. Journal of Forestry 62: 339-40.

Bickford, C.A., F.S. Baker and F.G. Wilson. 1957. *Stocking, normality and measurement of stand density*. Journal of Forestry 55: 99-104.

Bjorkbom, J.C. and R.S. Walters. 1986. *Allegheny hardwood regeneration response to even-age harvesting methods.* Research Paper NE-581. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Blum, B.M. 1963. *Excessive exposure stimulates epicormic branching in young northern hardwoods.* Research Note NE-9. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Blum, B.M. 1975. *Regeneration and uneven-aged silviculture: the state of the art*. pp. 67-87. *In*: Proceedings of Uneven-aged Silviculture and Management in the U.S. Symposium held at Morgantown, WV. General Technical Report W0-24. U.S. Department of Agriculture, Forest Service. Washington, DC.

Books, D.J. and C.H. Tubbs. 1970. *Relation of light to epicormic sprouting in sugar maple.* Research Note NC-93. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Boothby , R.D. and J. Buongiorno. 1985. *UNEVEN: A computer model of uneven-aged forest management*. Research Paper R3285. Madison, WI: Department of Forestry, University of Wisconsin.

Borman, F.H. and G.E. Likens. 1979. *Catastrophic disturbance and the steady state in northern hardwood forests*. American Scientist 67: 660-669.

Bormann, F.H. and G.E. Likens. 1979. *Pattern and process in a forested ecosystem.* New York: Springer-Verlag.

Botkin, D.B., J.F. Janak and J.R. Wallis. 1972. *Some ecological consequences of a computer model of forest growth*. Journal of Ecology 60:849-72.

Bowman, I. and J. Siderius. 1984. *Management guidelines for the protection of heronries in Ontario*. (Unpublished Report). Toronto: Wildlife Branch. Ontario Ministry of Natural Resources. 44 pp.

Bowman, J.C. 1996. *Two approaches to modeling marten* (Martes americana) *habitat suitability in northeastern Ontario*. M.Sc. thesis. Laurentian University, Sudbury, ON. 101 pp.

Boyce, S.G. and R.D. Carpenter. 1968. *Provisional grade specifications for hardwood growing-stock trees.* Research Paper NE-97. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Brand, G. 1981. *Simulating timber management in Lake States forests.* General Technical Report NC-69. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Bray, J.R. 1956 *Gap phase replacement in a maple-basswood forest.* Ecology. 37:598-600.

Broadfoot, J.D., T.J. Bellhouse and B.J. Naylor. 1994. *Central Region white-tailed deer habitat supply model.* CRST Technical Report No. 36. Central Region Science and Technology. Ontario Ministry of Natural Resources. 85 pp.

Brown, D.M., G.A. McKay and L.J. Chapman. 1974. *The climate of southern Ontario.* 2nd edition. Climatological Studies No. 5. Ottawa: Atmospheric Environment Service, Environment Canada.

Brown, G. 1973. *Direct seeding in Ontario*. pp. 119-124. *In*: Proceedings of Direct Seeding Symposium at Timmins, ON. J.H. Cayford (ed.). Publication No. 1339. Canadian Forest Service. Ottawa.

Bruce, D.S. and C.J. Heeney. 1974. A *silvicultural guide to the hard maple, yellow birch and hemlock working groups in Ontario.* Toronto: Forest Management Branch, Ontario Ministry of Natural Resources.

Burger, D. 1967. *Distribution and origin of parent soil materials in part of the Ottawa-Bonnechere River valleys, Ontario*. Canadian Journal of Earth Science 4: 397-411.

Burger, D. 1971. *Landtype pattern maps S1-71 to S11-71—Bobcaygeon, Limerick, Smith's Falls, Haliburton, Bancroft, Calabogie, Algonquin, Golden Lake, Ft. Coulonge, Mattawa, Deep River*. (Scale 1: 125 000). Maple, ON: Forest Research Branch, Ontario Ministry of Natural Resources.

Burger, D. and Z. Shidong. 1988. *An introductory comparison of forest ecological conditions in northeast China and Ontario, Canada.* Forestry Chronicle 64: 105-115.

Burkle, J.L. and S. Guttenberg. 1952. *Marking guides for oaks and yellow-poplar in the southern uplands.* Occasional Paper No. 125. New Orleans, LA: Southern Forest Experiment Station, U.S. Department of Agriculture.

Burns, R.M. 1983. *Silvicultural systems for the major forest types of the United States.* Agriculture Handbook No. 445. Washington, DC: Forest Service, U.S. Department of Agriculture.

Burns R.M and B.H.Honkala (eds.)1990 *Silvics of North America Vol.2 (Hardwoods).* U.S. Department of Agriculture, Forest Service, Washington, DC, Agricultural. Handbook. 654.

Burton, D.H. and N.H. Sloane. 1958. *Progress report on prescribed burning in the hard maple-yellow birch cover type in Ontario.* Forest Section Report No. 25. Toronto: Division of Research, Ontario Department Lands and Forests.

Burton, D.H., H.W. Anderson and L.F. Riley. 1969. *Natural regeneration of yellow birch in Canada*. pp. 55-73. *In*: Proceedings of the Birch Symposium at Durham, NH. E. Larson (ed.). U.S. Department of Agriculture, Northeast Forest Experiment Station. Upper Darby, PA.

Buse, L.J. 1992a. *Critical silvics of white pine as related to vegetation management*. TN-14. Thunder Bay, ON: Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources.

Buse, L.J. 1992b. *Critical silvics of bracken fern as related to vegetation management.* TN-16. Thunder Bay, ON: Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources,.

Buse, L.J. and F.W. Bell. 1992. *Critical silvics of selected crop and competitor species in northwestern Ontario*. Thunder Bay, ON: Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources. 138 pp.

Calvert, R.F. 1979. *Status of hardwood tree improvement*. pp. 161-166. *In*: Proceedings of Tree Improvement Symposium. Canada-Ontario Joint Forest Research Committee (*comp*.). J.B. Scarratt (ed.). Publication O-P-7. Canadian Forest Service, Great Lakes Forest Research Centre. Sault Ste Marie, ON.

Canada Soil Survey Committee. 1987. *The Canadian system of soil classification.* Compiled by the Subcommittee on Soil Classification, Research Publication No. 1646. Ottawa: Canadian Department of Agriculture.

Canadian Forest Service. 1995 *A descriptive forest inventory of Canada's forest regions* Information Report PI-X-122

Canham, C.D. and O.L. Loucks. 1984. *Catastrophic windthrow in the presettlement forests of Wisconsin*. Ecology 65: 803-809.

Carl, C.M., Jr. and H.W. Yawney. 1977. *Fall versus spring sowing of sugar maple seed in a nursery*. Tree Planters' Notes 28: 24-26.

Carmean, W.H., 1978. *Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan*. Research Paper NC-160. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN. 16 pp.

Carmean, W.H., J.T. Hahn and Rodney D. Jacobs. 1989. *Site index curves for forest tree species in the eastern United States*. General Technical Report NC-128. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN. 142 pp.

Carvell, K.L. 1967. *The response of understory oak seedlings to release after partial cutting.* Bulletin No. 553. Morgantown: Agriculture Experiment Station, West Virginia University.

Carvell, K.L. 1971. *Silvicultural aspects of intermediate cuttings*. pp. 60-64. *In*: Proceedings of Oak Symposium at Morgantown, WV. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station. Upper Darby, PA.

Carvell, K.L., C.B. Koch and D.J. Frederick. 1973. *The relationship between certain external characteristics and internal defect in black cherry.* Bulletin No. 615. Morgantown: Agriculture Experiment Station, West Virginia University.

Cech, F.C. 1971. *Tree improvement research in oak species*. pp. 55-59. *In*: Proceedings of Oak Symposium at Morgantown, WV. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station. Upper Darby, PA.

Chambers, B.A., B.J. Naylor, J. Nieppola, B. Merchant and P. Uhlig. 1997. *Field Guide to forest ecosystems of Central Ontario*. SCSS Field Guide FG-01. Ontario Ministry of Natural Resources, Southcentral Sciences Section, North Bay, ON.

Chapman, L.J. and D.F. Putnam. 1984. *The physiography of southern Ontario.* 3rd edition. Special Volume. 2. Toronto: Ontario Research Foundation, Ontario Geological Survey.

Chen, C.M., D.W. Rose and R.A. Leary. 1980. *How to formulate and solve optimal stand density over time problems for even-aged stands using dynamic programming.* General Technical Report NC-56. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Church, T.W., Jr. 1955. *Weeding: An effective treatment for stimulating growth of northern hardwoods.* Journal of Forestry 53: 717-19.

Church, T.W., Jr. 1960. *Factors affecting the development and survival of sugar maple sprouts*. pp. 32-35. *In*: Proceedings of Society of American Foresters Convention. Society of American Foresters. Washington, DC.

Clark, F.B. and R.F. Watt. 1971. *Silvicultural methods for regenerating oaks*. pp. 37-43. *In*: Proceedings of Oak Symposium at Morgantown, WV. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station. Upper Darby, PA.

Clausen, K.E. 1973. *Genetics of yellow birch.* Research Paper WO-18. Washington, DC: Forest Service, U.S. Department of Agriculture.

Clausen, K.E. and R.M. Godman. 1967. *Selecting superior yellow birch trees.* Research Paper NC-20. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Clausen, K.E. and R.M. Godman. 1969. *Bark characteristics indicate age and growth rate of yellow birch.* Research Note NC-75. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Clements, J.R. 1973. Report on symposia: *"Ecological impact of management practices in eastern deciduous forests"* and *"Synthesis of coniferous biome research, IBP, analysis of ecosystems project."* 24th Annual Meeting of AIBS, University of Massachusetts, Amherst, MA. Petawawa: National Forestry Institute, Canadian Forest Service.

Clutter, J.L., J.C. Fortson, L.V. Pienaar, G.H. Brister and R.L. Bailey. 1983. *Timber management: A quantitative approach.* Toronto: John Wiley & Sons.

Conover, D.F. and R.A. Ralston. 1959. *Results of crop tree thinning and pruning in northern hardwood saplings after 19 years*. Journal of Forestry 57: 551-57.

Cooley, J.H. 1964. *The effect of selection cutting on cull in northern hardwoods*. Journal of Forestry 62: 823-24.

Cowell, D.W. 1986. *Assessment of aquatic and terrestrial acid precipitation sensitivities for Ontario.* APIOS Report No. 009/86. Toronto: Ontario Ministry of the Environment.

Crawford, H.S. 1976. *Relationships between forest cutting and understory vegetation: an overview of eastern hardwood stands*. Research Paper NE-349. Forest Service., U.S. Department of Agriculture. 9 pp.

Crocker, W. and L.V. Barton 1957 *Physiology of seeds*. Chronica Botanica, Waltham, MA.

Crow, T.R. 1990 Tilia americana *L. - American basswood.* pp.784-791. *In*: R.M. Burns and B.H. Honkala (*comp.*). Silvics of North America, Volume 2, Hardwoods. Agricultural. Handbook 654. U.S. Department of Agriculture, Forest Service, Washington D.C.

Crow, T.R. 1992. *Population dynamics and growth patterns for a cohort of northern red oak* (Quercus rubra) *seedlings*. Oecologia 91: 192-200.

Crow, T.R. and F.T. Metzger. 1987. *Regeneration under selection cutting.* pp. 81-94. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002). State University of New York, College of Environmental Science and Forestry. Syracuse, NY.

Crow, T.R. and G.G. Erdman. *in press*. *Managing northern hardwoods in the Lake States*. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Crow, T.R., R.D. Jacobs, R.R. Oberg and C.H. Tubbs. 1981. *Stocking and structure for maximum growth in sugar maple selection stands.* Research Paper NC-199. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Cunningham, F.E. and R.J. Peterson. 1965. *Air-layering sugar maple.* Research Paper NE-42. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Dahir, S.E. and C.G. Lorimer. 1996 *Variation in canopy gap formation among developmental stages of northern hardwood stands* Canadian Journal of Forest Research 26:1875-1892

Dale, M.E., H.C. Smith and J.N. Pearcy. 1995. *Size of clearcut opening affects species composition, growth rate and stand characteristics*. Research Paper NE-698. Radner, PA: Northeast Forest Experiment Station. Forest Service, U.S. Department of Agriculture. 21 pp.

Daniel, T.W., J.A. Helms and F.S. Baker 1979 *Principles of silviculture.* New York: McGraw-Hill. 500 pp.

Davis, R. 1996. *Strategic forest management model: draft description and user's guide*. Sault Ste Marie, ON: Forest Management Branch, Ontario Ministry of Natural Resources. 86 pp.

DeBald, P.S. and J.J. Mendel. 1976. *SETS: Stand Evaluation Tools. 1. An individual-tree approach to making stand evaluations.* Research Paper NE-336. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

DeGraaf, R.M. 1987. *Managing northern hardwoods for breeding birds*. pp. 348-362 *In*: Managing Northern Hardwoods. R.D. Nyland (ed.). Publication. No. 87-03. Society of American Foresters. Washington, DC.

DeGraaf, R.M. and D.D. Rudis. 1986. *New England wildlife: habitat, natural history and distribution.* General Technical Report NE-108. Forest Service, U.S. Department of Agriculture. 491 pp.

DeGraaf, R.M., M. Yamasaki, W.B. Leak and J.W. Lanier. 1992. *New England wildlife: management of forested habitats*. General Technical Report NE-144. Forest Service, U.S. Department of Agriculture. 271 pp.

Desrochers, L. and J. Dunnigan. 1991. *Mobile sprayers for ground application of herbicides*. Spec. Report No. SR-79. Pointe Claire, QC. Forest Engineering Research Institute of Canada.

Dey, D. 1994. *Careful logging, partial cutting and the protection of terrestrial and aquatic habitat*. pp. 53-69. *In*: Logging Damage: The Problems and Practical Solutions. J.A. Rice (ed.). Forest Research Report No. 117. Ontario Ministry of Natural Resources, Ontario Forest Research Institute. Toronto.

Dey, D.C. and W.C. Parker. 1996. *Regeneration of red oak* (Quercus rubra *L.*) *using shelterwood systems: Ecophysiology, Silviculture and Management Recommendations.* Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Forest Research Information Paper No. 126. 59 pp.

Dickson, J.G., R.N. Conner and J.H. Williamson. 1983. *Snag retention increases bird use of a clear-cut*. Journal of Wildlife Management. 47: 799-804.

Dixon, R.M. 1982. *The use of prescribed burning in forest management by the Ministry of Natural Resources*. Toronto: Ontario Ministry of Natural Resources.

Dominy, S.W.J. 1987. *Silvicultural Equipment Reference Catalogues*. Toronto: Ontario Ministry of Natural Resources.

Downs, A.A. 1946. *Response to release of sugar maple, white oak and yellow poplar*. Journal of *Forestry* 44: 22-27.

Drinkwater, M.H. 1960. *Crown release of young sugar maple.* Technical Note No. 89. Forest Research Division, Canadian Department Northern Affairs and Natural Resources.

Ek, A.R. and R.A. Monserud. 1979. *Performance and comparison of stand growth models based on individual tree diameter-class growth*. Canadian Journal of Forest Research 9:231-44.

Erdman, G.G. 1986. *Developing quality second-growth stands*. *In*: Proceedings of a Conference on the Nothern Hardwood Resource. August 18-20, 1986. Haughton, MI: Michigan Tech. University.

Erdmann, G.G. 1983. *Tending valuable young northern and central hardwoods in natural stands*. pp. 76-95. *In*: Proceedings of Silviculture of Established Stands in North Central Forests Technical Conference at Duluth, MN. J.C. Stier (ed.). Publication No. 83-11. Society of American Foresters. Washington, DC.

Erdmann, G.G. 1987. *Methods of commercial thinning in even-aged northern hardwood stands*. pp. 191-210. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002): State University of New York, College of Environmental Science and Forestry. Syracuse, NY.

Erdmann, G.G. and R.M. Peterson, Jr. 1972. *Crown release increases diameter growth and bole sprouting of pole-size yellow birch.* Research Note NC-130. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Erdmann, G.G. and R.R. Oberg. 1973. *Fifteen-year results from six cutting methods in second-growth northern hardwoods.* Research Paper NC-100. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Erdmann, G.G., R.M. Godman and G.A. Mattson. 1975a. *Effects of crown release and fertilizer on small sawlog-sized yellow birch.* Research Paper NC-l l9. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Erdmann, G.G., R.M. Godman and R.R. Oberg. 1975b. *Crown release accelerates diameter growth and crown development of yellow birch saplings.* Research Paper NC-1 17. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Erdmann, G.G., R.M. Peterson, Jr. and R.M. Godman. 1981. *Cleaning yellow birch seedling stands to increase survival, growth and crown development*. Canadian Journal of Forest Research 11: 62-68.

Ernst, R.L. and W.H. Knapp. 1985. *Forest stand density and stocking: Concepts, terms and the use of stocking guides*. General Technical Report WO-44. Washington, DC: Forest Service, U.S. Department of Agriculture.

Euler, D. and L. Thurston. 1977. *Characteristics of hemlock stands related to deer use in east-central Ontario.* pp. 93-102. *In*: Transcripts of the 11th Meeting of the Northeast Deer Study Group. F. Potvin and J. Huot (eds.). Ministry of Tourism, Chasse, Peche, Quebec, QC.

Expert Committee on Soil Survey. 1983. *The Canadian soil information system (CanSIS): Manual for describing soils in the field.* Revised 1982. Compiled by the Working Group on Soil Survey Data . J.H. Day (ed.). Contribution No. 82-52. Ottawa: Agriculture Canadian Resources Research Institute.

Eyre, F.H. and W.M. Zillgitt. 1953. *Partial cuttings in northern hardwoods in the Lake States.* Technical Bulletin No. 1076. Washington, DC: Forest Service, U.S. Department of Agriculture.

Farmer, R.E., Jr. 1973. *Decision making for development and use of genetically improved hardwoods*. Journal of Forestry 71: 74-78.

Farmer, R.E., Jr. and K.D. Besemann. 1974. *Rooting cuttings from physiologically mature black cherry*. Silvae Genetica 23: 104-5.

Farrar, J.L. 1995. *Trees in Canada*. Markham, ON: Fitzhenry and Whiteside Ltd.

Ffolliott, P.F., K.N. Brooks and D.P. Guertin. 1984. *Multiple-resource modeling: Lake States' application*. Northern Journal of Applied Forestry 1: 80-84.

Foster, N.W. 1985. *Neutralization of acid precipitation within a maple-birch ecosystem*. Tappi Journal 68: 104-6.

Foster, N.W. and J.A. Nicolson. 1984. *Acid precipitation and water quality within a tolerant hardwood stand and soil*. pp. 337-342. *In*: Proceedings of International Forestry Congress at Quebec City, QC.

Fowells, H.A., (*compiler*). 1965. *Silvics of forest trees of the United States.* Agriculture Handbook No. 271. U.S. Department of Agriculture, Forest Service. Washington, DC.

Francis, J.K. and D.L. Bivens. 1985. *Yellow-poplar and black cherry grow well after underplanting and release*. Tree Planters' Notes 36: 8-9.

Frelich, L.E. and C.G. Lorimer. 1991. *Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes Region*. Ecological Monograph. 61: 145-164.

Froehlich, H. A., D. E. Aulerich and R. Curtis, 1981. *Designing skid trail systems to reduce soil impacts from tractive logging machines.* Research Paper 44. Corvallis, OR: Forest Research Laboratory, School of Forestry, Oregon State University. 15 pp.

Frothingham , E.H. 1915. *The eastern hemlock*. Bulletin No. 152. Washington, DC: Forest Service, U.S. Department of Agriculture. 43 pp.

Gabriel, W. J. and P.W. Garrett. 1984. *Pollen vectors in sugar maple (Acer saccharum)*. Canadian Journal of Botany 62: 2889-90.

Gabriel, W.J., J.W. Marvin and F.H. Taylor. 1961. *Rooting greenwood cuttings of sugar maple: Effect of clone and medium.* Station Paper No. 144. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Gall, W.R. and K.A. Taft. 1973. *Variation in height growth and flushing of northern red oak* (Quercus rubra *L*.). pp.190-199. *In*: Proceedings of Twelfth Southern Forest Tree Improvement Conference at Baton Rouge, LA. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. New Orleans, LA.

Gevorkiantz, S.R. 1956. *Managing northern hardwoods for quality increment*. Journal of Forest 54: 836-840.

Gingrich, S.F. 1964. *Criteria for measuring stocking in forest stands*. pp.198-201. *In*: Proceedings of Society of American Foresters Conference. Society of American Foresters. Washington, DC.

Gingrich, S.F. 1967. *Measuring and evaluating stocking and stand density in upland hardwood forests in the central states*. Forest Science 13: 38-53.

Godman, R.M. 1986. *Silvicultural considerations in thinning*. pp. 26-30. *In*: Proceedings of Hardwood Thinning Opportunities in the Lake States Symposium at Escanaba, MI. J.A. Sturos (*comp.*). General Technical Report NC-113. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. *no date.(*c). *Hardwood planting.* Northern Hardwood Notes No. 3.07. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. *no date.(*e). *Prescribed burning for the birches and hemlock.* Northern Hardwood Notes No. 3.06. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. *no date* (f) *Thinning stump sprouts*. Northern Hardwood Notes No. 3.11. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. and C.H. Tubbs. 1973. *Establishing even-age northern hardwood regeneration by the shelterwood method: A preliminary guide.* Research Paper NC-99. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. and D.A. Marquis. 1969. *Thinning and pruning in young birch stands*. *In*: Proceedings of the Birch Symposium at Durham, NH. E. Larson (ed.). pp. 119-127. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Godman, R.M. and D.J. Books. 1971. *Influence of stand density on stem quality in pole-size northern hardwoods.* Research Paper NC-54. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station, St. Paul, MN.

Godman R.M. and G.A. Mattson 1976 *Seed crops and regeneration problems of 19 species in northeastern Wisconsin.* Research Paper NC-123. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN. 5 pp.

Godman, R.M. and G.A. Mattson. 1980. *Low temperatures optimum for field germination of northern red oak*. Tree Planters' Notes 31*: 3*2-34.

Godman, R.M. and G.A. Mattson. *no date. Direct seeding.* Northern Hardwood Notes No. 3.08. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Godman, R.M. and G.G. Erdmann. 1983. *Factors in the improvement of stem quality*. pp. 69-75. *In*: Proceedings of Silviculture of Established Stands in North Central Forests Technical Conference at Duluth, MN. J.C. Stier (ed.). Publication No. 83-11. Society of American Foresters. Washington, DC.

Godman, R.M. and G.G. Erdmann. *no date. Regenerating yellow birch in the Lake States.* Northern Hardwood Notes No. 3.04. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN.

Gordon A.M., J.A. Simpson and P.A. Williams. 1995. *Six - year response of red oak seedlings planted under a shelterwood in Central Ontario.* Canadian Journal of Forest Research. 25 (4): 603-613.

Gordon, A.G. 1992. *The red spruce option: red spruce and the hemlock connection*. 99-114 pp. *In*: Regenerating Conifer Cover in Deer Yards. A Workshop held in North Bay December 4-5 1990. B. Naylor and L. Thompson (eds.). Technical Report No. 28. Ontario Ministry of Natural Resources, Central Ontario Forest Technology Development Unit. North Bay, ON.

Gottschalk, K.W. 1985. *Effects of shading on growth and development of northern red oak, black oak, black cherry and red maple seedlings*. I. Height, diameter and root/shoot ratio. pp. 189-195 *In*: Proceedings of Fifth Central Hardwoods Forest Conference at University of Illinois. J.O. Dawson and K.A. Majerus (eds.). Society of American Foresters Publication No. 85-05., University of Illinois, Department of Forestry. Urbana-Champaign, IL.

Gottschalk, K.W. and D.A. Marquis. 1982. *Survival and growth of planted red oak and white ash as affected by residual overstory density, stock size and deer browsing*. pp. 125-140. *In*: Proceedings of Fourth Central Hardwoods Forest Conference at University of Kentucky. R.N. Muller (ed.).

Grisez, T.J. 1975. *Flowering and seed production in seven hardwood species.* Research Paper NE-315. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Grisez, T.J. and J.J. Mendel. 1972. *The rate of value increase for black cherry, red maple and white ash.* Research Paper NE-231. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Gross, H.L. 1985. *The impact of insects and diseases on the forests of Ontario.* Information Report O-X-366. Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Gunter, J.E. 1983. *Analysis of silvicultural investments*. pp. 45-52. *In*: Proceedings of Silviculture of Established Stands in North Central Forests Technical Conference at Duluth, MN. J.C. Stier (ed.). Publication No. 83-11. Society of American Foresters. Washington, DC.

Guyette, R. and D. Dey. 1995. *A history of fire, disturbance and growth of a red oak stand in the Bancroft District, Ontario.* Forest Research Information Paper No. 119. Ontario Forest Research Institute. Ontario Ministry of Natural Resources. pp. 14.

Haddon, B.D. (ed.). 1988. *Forest inventory terms in Canada*. 3rd edition. Canadian Forest Inventory Committee, Forestry Canada. 109 pp. English.

Hamilton, G.J. 1969. *The dependence of volume increment of individual trees on dominance, crown dimensions and competition*. Forestry 42 (2): 133-44.

Hannah, P.R. 1978. *Growth of large yellow birch saplings following crop tree thinning*. Journal of Forestry 76: 222-23.

Hannah, P.R. 1988b. *Vegetative propagation of yellow birch from stem cuttings*. Tree Planters' Notes 39: 37-42.

Hannah, P.R. and T.L. Turner. 1981. *Growth and survival of yellow birch, sugar maple and white ash after fall planting*. Tree Planters' Notes 32: 30-32.

Hansen, G.D. 1984. *A computer simulation model of uneven-aged northern hardwood stands under the selection system*. Report No. 3 (ESF-84-017). Syracuse, NY: College of Environmental Science and Forestry, State University of New York.

Hansen, G.D. and R.D. Nyland. 1987. *Effects of diameter distribution on the growth of simulated uneven-aged sugar maple stands*. Canadian Journal of Forest Research 17: 1-8.

Harlow, R.F. and R.L. Downing. 1969. *The effects of size and intensity of cut on production and utilization of some deer foods in the southern Appalachians*. Trans. NE Fish & Wildlife. Conference. 26: 45-55.

Hatcher, R.J. 1966. *Yellow birch regeneration on scarified seedbeds under small canopy openings*. Forestry Chronicle 42: 350-58.

Healy, W.M. 1987. *Habitat characteristics of uneven-aged stands*. pp. 338-347 *In:* Managing Northern Hardwoods. R.D. Nyland (ed.). Publication No. 87-03. Society of American Foresters. Washington, DC.

Healy, W.M., R.T. Brooks and R.M. DeGraaf. 1989. *Cavity trees in sawtimber-size oak stands in central Massachusetts.* Northern Journal of Applied Forestry 6: 61-65.

Heeney, C.J. 1974. *Applied silviculture in the Great Lakes-St. Lawrence and Deciduous Forest Regions of Ontario*. Paper presented at the Ontario Professional Foresters Association Workshop at Dorset, ON.

Heij, W. and N.A. Leek. 1981. *Impacts of wood harvesting technology on soil and vegetation*. pp. 21-32. *In*: Proceedings of Seventeenth IUFRO World Congress (Interdivisional) in Kyoto, Japan.

Hendrickson, O., J.B. Robinson and L. Chatarpaul. 1982. *The microbiology of forest soils:* A *literature review.* Information Report PI-X-l9. Petawawa: National Forestry Institute, Canadian Forest Service.

Hepting, G.H., K.H. Garren and P.W. Warlick. 1940. *External features correlated with top rot in Appalachian oaks.* Journal of Forestry 38: 873-876.

Hesterberg, G.A. 1957a. *Deterioration of sugar maple following logging damage.* Station Paper No. 51. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Hesterberg, G.A. 1957b. *Logging damage risk classification for sugar maple.* Technical Note No. 488. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Hibbs, D.E. and W.R. Bentley. 1984. *A growth model for red oak in New England*. Canadian Journal of Forest Research 14: 250-54.

Higgs, B. 1981. *Hardwood silviculture: A look at the pre-commercial thinning and planting programs underway at Valley Forest Products Ltd*. Pulp and Paper Canada 82 (7): 26-32.

Hills, G.A. and W.G.E. Brown. 1955. *The sites of the University of Toronto Forest*. Paper prepared for the Eighth Annual Meeting of the Northeast Forest Soils Conference, Dorset, ON. August 1-4, 1955.

Hills, G.A. 1959. *A ready reference to the description of the land of Ontario and its productivity*. Toronto: Ontario Department Lands and Forests.

Hills, G.A. 1960. *The soils of the Canadian shield*. Agriculture Institute Review 15 (2): 41-43.

Hilt, D.E. 1985a. *OAKSIM: An individual-tree growth and yield simulator for managed, even-aged upland oak stands*. Research Paper NE-562. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Hilt, D.E. 1985b. *Species composition of young central hardwood stands that develop after clearcutting*. pp. 11-14. *In*: Proceedings of Fifth Central Hardwoods Forest Conference at the University of Illinois. J.O. Dawson and K.A. Majerus (eds.). Society of American Foresters Publication No. 85-05. University of Illinois, Department of Forestry. Urbana-Champaign, IL.

Holcomb, C.J. and C.A. Bickford. 1952. *Growth of yellow poplar and associated species in West Virginia as a guide to selective cutting.* Station Paper No. 52. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Hollstedt, C. 1992. *Critical silvics of large-leaved aster as related to vegetation management.* TN-15. Thunder Bay, ON: Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources

Holowacz, J. 1960. *Progress report on prescribed burning in the hard maple-yellow birch cover type in Ontario 1958-1959.* Forest Section Report No. 37. Toronto: Division of Research, Ontario Department Lands and Forests.

Honer, T.G. 1967. *Standard Volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada*. Information Report FMR-X-5. Forest Management Research and Service Institute.

Honer, T.G., M.F. Ker and I.S. Alemdag. 1983. *Metric timber tables for the commercial tree species of central and eastern Canada*. Information Report M-X-140. Fredericton NB, Maritimes Forest Research Centre. Environment Canada, Canadian Forestry Service. 139 pp.

Hopper, G.M., D.W. Smith and D.J. Parrish. 1985. *Germination and seedling growth of northern red oak: Effects of stratification and pericarp removal*. Forest Science 31: 31-39.

Horton, K.W. 1964. *Scarifying and screefing for regeneration*. Canadian Lumberman (January): 1-4.

Hough, A.F. 1959. *Zoning for the management of black cherry on the Allegheny Plateau*. Journal of Forestry 57: 353-57.

Houston, D.R. 1981. *Stress-triggered tree disease: The diebacks and declines.* Information Report NE-41-81. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Hunter, M.L. 1990. *Wildlife, forests and forestry*. Englewood Cliffs, NJ: Prentice Hall. 370 pp.

Huntzinger, H.J. 1964. *Germination, survival and first-year growth of black cherry under various seedbed and supplemental treatments.* Research Note NE-26. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Husch, B., C.I. Miller and T.W. Beers. 1972. *Forest Mensuration*. 2nd edition. New York: The Ronald Press Company. 410 pp.

Hutnik, R.J. 1958. *Converting all-aged stand tables by 1-inch diameter classes to 2-inch classes*. Journal of Forestry 56: 142-143.

Hynard, P.P. 1984. *A decision-making model for forest managers using economic considerations.* Toronto: Ontario Ministry of Natural Resources.

Innes, J.L. 1987. *Air Pollution and Forestry*. U.K. Forestry Commission Bulletin 70. Edinburgh, Scotland. United Kingdom Forestry Commission.

Irwin, J.R. 1988. *Key to silvicultural prescriptions for areas of natural and scientific interest.* Cambridge: Ontario Ministry of Natural Resources.

Isebrands, J.G. and T.R. Crow. 1985. *Techniques for rooting juvenile softwood cuttings of northern red oak*. pp. 11-14. *In*: Proceedings of Fifth Central Hardwoods Forest Conference at the University of Illinois. J.O. Dawson and K.A. Majerus (eds.). Society of American Foresters Publication No. 85-05. University of Illinois, Department of Forestry. Urbana-Champaign, IL

Jackson, G.L., G.D. Racey, J.G. McNicol and L.A. Godwin. 1991. *Moose habitat interpretation in Ontario*. NWOFTDU Technical Report 52. Northwestern Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources. 74 pp.

Jacobs, R.D. 1968. *Growth and yield*. pp. 96-104. *In*: Proceedings of Sugar Maple Conference at Houghton, MI. U.S. Department of Agriculture, Forest Service. Washington, DC.

Jarvis, J.M. 1956 *An ecological approach to tolerant hardwood silviculture.* Canadian Department of Northern Affairs and National Resources. Ottawa, Forest Research Division, Technical Note 43. 43 pp.

Johnson, F., et al. 1996. *Artificial regeneration of Ontario's forests: species and stock manual*. Forest Research Information Paper No. 131. Ontario Forest Research Institute. Ontario Ministry of Natural Resources.

Johnson, G.R., Jr. 1983. *Removing cull acorns from a water-willow oak acorn lot using salt solutions*. Tree Planters' Notes 34*:* 10-12.

Johnson, P.S. 1974. *Survival and growth of northern red oak seedlings following a prescribed burn.* Research Note NC-177. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Johnson, P.S. 1976. *Modal development of regeneration in clearcut red oak stands in the driftless area*. pp. 455-475. *In*: Proceedings of First Central Hardwoods Forest Conference at Carbondale, IL. J.S. Fralish, G.T. Weaver and R.C. Schlesinger (eds.). U.S. Department of Agriculture, Forest Service. Washington, DC.

Johnson, P.S. 1984b. *Responses of planted northern red oak to three overstory treatments*. Canadian Journal of Forest Research 14: 536-42.

Johnson, P.S. 1994. *The Silviculture of northern red oak*. pp. 33-68. *In*: Biology and Silviculture of Northern Red Oak in the North Central Region: A Synopsis. J.G. Isebrands and R.E. Dickson (*comps*). General Technical Report NC-173. U.S. Department of Agriculture, Forest Service.

Johnson, P.S. and R. Rogers. 1980. *Predicting growth of individual stems within red oak sprout clumps*. pp. 420-439. *In*: Proceedings of Third Central Hardwoods Conference at Columbia, MO. H.E. Garrett and G.S. Cox (eds.) University of Missouri, Columbia, MO.

Johnson, P.S. and R. Rogers. 1984. *Predicting 25th-year diameters of thinned stump sprouts of northern red oak*. Journal of Forestry 82: 616-619.

Johnson, P.S. and R.D. Jacobs. 1981. *Northern red oak regeneration after pre-herbicided clearcutting and shelterwood removal cutting.* Research Paper NC-202. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Johnson, P.S. and R.M. Godman. 1983. *Pre-commercial thinning of oak, basswood and red maple sprout clumps*. pp. 124-139. *In*: Proceedings of Silviculture of Established Stands in North Central Forests Technical Conference. J.C. Stier (ed.). Publication No. 83-11. Society of American Foresters. Washington, DC.

Johnson, P.S., C.D. Dale., K.R. Davidson and J.R. Law. 1986. *Planting northern red oak in the Missouri Ozarks: A prescription*. Northern Journal of Applied Forestry 3: 66-68.

Johnson, P.S., R.D. Jacobs, A.J. Martin and E. Godel. 1989. *Regenerating northern red oak: three successful case histories*. Northern Journal of Applied Forestry. 6: 174-178.

Johnson, R.L. 1979. *Adequate oak regeneration: A problem without a solution?* pp. 59-65. *In*: Proceedings of Seventh Annual Hardwood Symposium of the Hardwood Research Council at Cashiers, NC. U.S. Department of Agriculture, Forest Service. Atlanta, GA.

Johnson, R.L. and R.M. Krinard. 1985. *Regeneration of oaks by direct seeding*. pp. 56-65. *In*: Proceedings of Third Southeastern Hardwoods Symposium at Atlanta, GA. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. New Orleans, LA.

Kasile, J.D. 1982. *Hardwood lumber, log and tree grading*. pp. 108-109. *In*: Proceedings of Society of American Foresters Convention at Cincinnati, OH. Society of American Foresters Publication No. 83-04. Society of American Foresters. Washington, DC.

Keetch, J.J. 1944. *Sprout development on once-burned and repeatedly-burned areas in the southern Appalachians.* Technical Note No. 59. Asheville, NC: Appalachian Forest Experiment Station, U.S. Department of Agriculture.

Kelty, M.J. and R.D. Nyland. 1983. *Hardwood browse production following shelterwood cutting*. Journal of Wildlife Management. 47: 1216-1220.

Kelty, M.J. 1988 *sources of hardwood regeneration and factors that influence these sources.* pp. 17-30. *In*: H.C. Smith A.W. Perkey and W.E Kidd (eds.). Proceedings of a Workshop on Guidelines for Regenerating Appalachian Hardwood Stands, Morgantown, WV. SAF Publication. 88-03.

Kimmins, J.P. and K.A. Scoullar. 1984. *FORCYTE-10: A user's manual*. Vancouver, BC: Faculty of Forestry, University of British Columbia.

Kirk, D.A. and B.J. Naylor. 1996. *Habitat requirements of the pileated woodpecker* (Dryocopus pileatus) *with special reference to Ontario*. SCST Technical Report No. 46. Ontario Ministry of Natural Resources, Southcentral Sciences Section. North Bay, ON. 49 pp.

Kirk, D.A. and B.J. Naylor. (*in prep.*). *Response of pileated woodpeckers and other cavity using birds to selection and shelterwood harvest in Algonquin Park*. SCST Technical Report, Ontario Ministry of Natural Resources.

Kriebel, H.B. 1957. *Patterns of genetic variation in sugar maple.* Research Bulletin No. 791. Wooster: Ohio Agriculture Experiment Station, U.S. Department of Agriculture.

Kriebel, H.B. 1963. *Some techniques for early diagnosis of genotype in* Acer saccharum *L.* pp. 68-70. DerZuchter 6 Sonderheft.

Kriebel, H.B. and W.J. Gabriel. 1969. *Genetics of sugar maple.* Research Paper W0-7. Washington, DC: Forest Service, U.S. Department of Agriculture.

Lamson, N.I. 1983. *Pre-commercial thinning increases diameter growth of Appalachian hardwood stump sprouts*. Southern Journal of Applied Forestry 7: 93-97.

Lamson, N.I. and H.C. Smith. 1978. *Response of crop tree release: Sugar maple, red oak, black cherry and yellow-poplar saplings in a 9-year-old stand.* Research Paper NE-354. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Lamson, N.I. and H.C. Smith. 1987. *Pre-commercial treatment of 15- to 40-year old northern hardwood stands*. pp. 160-175. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002). State University of New York, College of Environmental Science and Forestry. Syracuse, NY.

Lamson, N.I. and R.E. McCay. 1978. *How to determine whether forest fertilization pays*. pp. 320-327. *In*: Proceedings of Second Central Hardwoods Forest Conference at West Lafayette. *In*: P.E. Pope (ed.). U.S. Department of Agriculture, Forest Service. Washington, DC.

Lamson, N.I., H.C. Smith and G.W. Miller. 1985. *Logging damage using an individual-tree selection practice in Appalachian hardwood stands*. Northern Journal of Applied Forestry 2: 117-20.

Land, D., W.R. Marion and T.E. O'Meara. 1989. *Snag availability and cavity nesting birds in slash pine plantations.* Journal of Wildlife Management. 53: 1165-1171.

Lavallee, A. 1968. *Determination de la qualite de l'erable a sucre d'apres des signes apparents de carie.* Forestry Chronicle 44 (4): 5-10.

Lavallee, A. and M. Lortie. 1968. *Relationships between external features and trunk rots in living yellow birch*. Forestry Chronicle 44 (2): 5-10.

Leak, W.B. 1963. *Calculation of "q" by least squares method*. Journal of Forestry 61: 227-28.

Leak, W.B. 1980. *Rapid economic analysis of northern hardwood stand improvement options.* Research Note NE-296. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Leak, W.B. and C.H. Tubbs. 1983. *Per cent crown cover tables for applying the shelterwood system in New England.* Research Note NE-313. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Leak, W.B. and J.H. Gottsacker. 1985. *New approaches to uneven-age management in New England*. Northern Journal of Applied Forestry 2: 28-31.

Leak, W.B. and R.W. Wilson, Jr. 1958. *Regeneration after cutting of old-growth northern hardwoods in New Hampshire.* Station Paper No. 103. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Leak, W.B. and S.M. Filip. 1975. *Uneven-aged management of northern hardwoods in New England.* Research Paper NE-332. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Leak, W.B. and S.M. Filip. 1977. *Thirty-eight years of group selection in New England northern hardwoods.* Journal of Forestry 75: 641-43.

Leak, W.B., D.S. Solomon and P.S. DeBold. 1987. *Silvicultural guide for northern hardwood types in the Northeast.* Revised edition. Research Paper NE-603. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Leak, W.B., D.S. Solomon and S.M. Filip. 1969. *A silvicultural guide for northern hardwoods in the Northeast.* Research Paper NE-143. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Ledig, F.T. 1992. *Human Impacts on genetic diversity in forest ecosystems*. Oikos 63: 87-108.

Ledig, F.T. and D.R. Korbobo. 1983. *Adaptation of sugar maple populations along altitudinal gradients: photosynthesis, respiration and specific leaf weight.*

LeDoux, C.B. 1986. *MANAGE: A computer program to estimate costs and benefits associated with eastern hardwood management.* General Technical Report NE-112. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Lee, H.T., W. Bakowsky, J. Riley, P. Neave, H. Stewart, P. Neave, H. Stewart, K. Coleman and P. Uhlig.1996. An ecological community classification for Southern Ontario: A first approximation. Ontario Ministry of Natural Resources Science and Technology. Transfer Unit, Aurora, ON.

Lewis, D., G. Gillespie and B. Naylor. (*in prep*.). *The impact of timber harvest on the persistence of beaver colonies: a preliminary study.* SCST Technical Report No. 47. Ontario Ministry of Natural Resources. 9 pp.

Li, C., M. Ter-Mikaelian and A. Perera. 1996. *Ontario fire regime model: its background, rationale, development and use*. FLEP Report No. 25. Ontario Forest Research Institute, Ontario Ministry of Natural Resources.

Li, P., J. Mackay and J. Bousquet. 1992. *Genetic diversity in Canadian hardwoods: implications for conservation*. The Forestry Chronicle 68(6):709-19.

Lockard, C.R., J.A. Putnam and R.D. Carpenter. 1963. *Grade defects in hardwood lumber and logs.* Agriculture Handbook No. 244. Washington, DC: Forest Service, U.S. Department of Agriculture.

Loftis, D.L. 1990. *A shelterwood method for regenerating red oak in the southern Appalachians*. Forest Science. 36: 917-929.

Lorimer, C.G. 1983. *A test of the accuracy of shade-tolerance classifications based on physiognomic and reproductive traits*. Canadian Journal of Botany 61: 1595-98.

Lorimer, C.G., J.W. Chapman and W.D. Lambert. 1994. *Tall understorey vegetation as a factor in the poor development of oak seedlings beneath mature stands*. Journal of Ecology. 82: 227-237.

Louter, J.H., M. Kershaw and A.M. Gordon. 1993. *The autecology of competing non-crop vegetation on old field sites in southern Ontario*. Brockville, ON: Science & Technology Transfer Unit (Southern Region). Ontario Ministry of Natural Resources. 143 pp.

Love, D.V., A.F. Beckwith and Z.J.R. Morawski. 1972. *Studies of land productivity for hardwoods in southern Ontario.* Report No. 6. Toronto: Canada Land Inventory Program, Agricultura1 and Rural Development Ministry, Canadian Department Regional Economic Expansion.

MacArthur, J.D. and J.W. Fraser. 1963. *Low temperature germination of some eastern Canadian tree seed*. Forestry Chronicle 39: 478-79.

MacArthur, R.H. and J.W. MacArthur. 1961. *On bird species diversity*. Ecology 42: 594-598.

MacKey, B.G., D.W. McKenney, Y-Q. Yang, J.P. McMahon and M.F. Hutchinson. 1996. Site regions revisited: A climatic analysis of Hill's site regions for the Province of Ontario using a parametric method. Canadian Journal of Forest Research 26(3): 333-354.

Malhotra, S.S. and R.A. Blauel. 1980. *Diagnosis of air pollutant and natural stress symptoms on forest vegetation in western Canada.* Information Report NOR-X-228. Edmonton: Northern Forestry Centre, Canadian Forest Service.

Mallik, A.U., G.W. Peterson and F.W. Bell. 1996. *Vegetative and seedling regeneration of pin cherry* (Prunus pensylvanica): *efficacy of herbicide treatment*. NODA Note No. 21. Canadian Forestry Service / Ontario Ministry of Natural Resources. 4 pp.

Manion, P.D. 1981. *Tree disease concepts.* Englewood Cliff, NJ: Prentice-Hall Inc.

Marden, R.M. and C.L. Stayton. 1970. *Defect indicators in sugar maple: A photographic guide.* Research Paper NC-37. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Marquis, D.A. 1969. *Thinning in young northern hardwoods: 5 year results.* Research Paper NE-139. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Marquis, D.A. 1975. *Application of uneven-aged silviculture and management on public and private lands*. pp. 25-61. *In*: Proceedings of Uneven-aged Silviculture and Management in the U.S. Symposium at Morgantown, WV. General Technical Report W0-24. U.S. Department of Agriculture, Forest Service. Washington, DC.

Marquis, D.A. 1979. *Shelterwood cuttings in Allegheny hardwoods*. Journal of Forestry 77: 140-44.

Marquis, D.A. 1986. *SILVAH: A stand analysis, prescription and management simulator program for hardwood stands in the Alleghenies*. pp. 1-17. *In*: Proceedings of Forestry Micro Computer Software Symposium at Morgantown, WV.

Marquis, D.A. and R.L. Ernst. 1992. *User's guide to SILVAH*. Forest Technical Report NE-162. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA. 124 pp.

Marquis, D.A. and R. Brenneman. 1981. *The impact of deer on forest vegetation in Pennsylvania.* General Technical Report NE-65. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Marquis, D.A., R.L. Ernst and S.L. Stout. 1984. *Prescribing silvicultural treatments in hardwood stands of the Alleghenies.* General Technical Report NE-96. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Marquis, D.A., R.L. Ernst and S.L Stout. 1990. *Prescribing Silvicultural Treatments in Hardwood Stands of the Alleghenies (revised).* General Technical Report NE-96. Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture.

Marquis, D.A., R.L. Ernst and S.L Stout. 1992. *Prescribing Silvicultural Treatments in Hardwood Stands of the Alleghenies (revised).* General Technical Report NE-96. Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture.

Martell, D.L. 1978. *The use of historical fire weather data for prescribed burn planning*. Forestry Chronicle. 54: 96-98.

Maynard, C.A., R.P. Overton and L.C. Johnson. 1987. *The silviculturist's role in tree improvement in northern hardwoods*. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002). pp. 35-45. Syracuse: College of Environmental Science and Forestry, State University of New York.

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, NEST Field Guide G-001.

McCauley, O.D. and D.A. Marquis. 1972. *Investment in pre-commercial thinning of northern hardwoods.* Research Paper NE-245. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

McEwen, J.K., D.H. Burton and G.A. Sinclair. 1958.A *description and evaluation of cultural treatments in the tolerant hardwood stands of the Lindsay District.* Forest Section Report No. 19. Toronto: Division of Research, Ontario Department Lands and Forests.

McGill, D. J. Martin, R. Rogers and P.F. Johnson, 1991. *New stocking charts for northern red oak*. Forest Research Note No. 277. University of Wisconsin , Madison, WI. 8 pp.

McIlveen, W.D., D.L. Mclaughlin and R. Arnup. 1989. *A Survey to Document the Decline Status of the Sugar Maple Forest of Ontario - 1986*. Ontario Ministry of the Environment.

McIlveen, W.D., S.T. Rutherford and S.N. Linzon. 1986. A *historical perspective of sugar maple decline within Ontario and outside of Ontario.* Report ARB-141-86-Phyto. Air Resources Branch, Ontario Ministry of the Environment. Toronto.

McLaughlan, M.S. 1992. *Hexazinone and granular herbicide applicators: a review of the herbicide and available application equipment.* Technical Rep #71. Thunder Bay, ON: Northwest Science and Technology. Ontario Ministry of Natural Resources.

McLaughlan, M.S., D. Myketa and F.W. Bell. 1996. *Managing vegetation with herbicides: a review of glyphosate, 2,4-D, hexazinone, triclopyr and simazine.* Northwest Science & Technology. TN-37, 12 pp. *In*: Bell, F.W., M. McLaughlan and J. Kerley (*comp.*). *Vegetation Management Alternatives - A Guide to Opportunities*. Thunder Bay, ON: Ontario Ministry of Natural Resources.

McLaughlin D.L. 1996. *A Decade of Forest Health Monitoring in Canada: Evidence of Air Pollution Effects*. Ontario Ministry of Environment and Energy.

McLaughlin, D.L. 1987. *Maple decline in Ontario: Situation/research status report*. *In*: Proceedings of Maplefest '87 at Grand Falls, NB. Toronto: Air Resources Branch, Ontario Ministry of the Environment.

McLaughlin, D.L., D.E. Corrigan and W.D. McIlveen. 1992. *Etiology of Sugar Maple Decline at Selected Sites in Ontario (1984-1990).* Ontario Ministry of the Environment.

McLean, M.M. 1970. *Quality of hard maple logs in Algonquin Park*. Toronto: Forest Research Branch, Ontario Department Lands and Forests. Photocopy.

McLean, M.M. 1976. *Tree marking objectives and training tree markers*. Dorset, ON: Forest Research Centre, Ontario Ministry of Natural Resources. Photocopy.

McLean, M.M. 1987a. *Stand growth after thinning 61-80 year age-class in tolerant hardwoods*. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute. Ontario Ministry of Natural Resources. Photocopy.

McLean, M.M. 1987b. *Tolerant hardwood thinning studies: Algonquin Park*. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute. Ontario Ministry of Natural Resources. Photocopy.

McLean, M.M. 1987c. *Selection cutting in tolerant hardwoods: Algonquin Park*. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources. Photocopy.

Menard, G., R. McNeil and A. Bouchard. 1982. *Les facterus indicatifs de la divesite des peuplements d'oiseaux forestiers du sud du Quebec*. Nature Canada. 109: 39-50.

Mendel, J.J. and G.R. Trimble, Jr. 1969. *The rate of value increase for yellow poplar and beech.* Research Paper NE-140. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Mendel, J.J., T.J. Grisez and G.R. Trimble, Jr. 1973. *The rate of value increase for sugar maple.* Research Paper NE-250. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Meyer, H.A. 1952. *Structure, growth and drain in balanced, uneven-aged forests*. Journal of Forestry 50*:* 85-92.

Meyer, W.H. 1929. *Yields of second-growth spruce and fir in the northeast*. Technical Bulletin No. 142. Washington, DC: Forest Service, U.S. Department of Agriculture. 52 pp.

Miller, G.W., T.M. Schuler and H.C. Smith. 1995. *Method for applying group selection in central Appalachian hardwoods*. Research Paper NE-696. Radner, PA: Northeast Forest Experiment Station. Forest Service, U.S. Department of Agriculture. 11 pp.

Miller, R.J. and M.E. Woods. 1989. *MAPLE1: A sugar maple growth model*. Mensuration Unit Report. Sault Ste Marie, ON: Ontario Ministry of Natural Resources. 12 pp.

Miller, G.W., K.A. Elliott, E.P. Boysen. 1998 (*in press*). *The Central Appalachian hardwoods experience provides silvicultural tools for Ontario.* OMNR Southcentral Science Section, 45 pp.

Minckler, L.S. and S.F. Gingrich. 1970. *Relation of crown width to tree diameter in some upland hardwood stands of southern Illinois.* Research Note NC-99. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Mitchell, K.J. 1988. *SYLVER: Modeling the impact of silviculture on yield, lumber value and economic return*. Forestry Chronicle 64: 127-131.

Mize, C.W. and R.V. Lea. 1977. *Vigor and risk classifications for northern hardwoods*. Northern Logger and Timber Processor 26(5): 22-23, 32-33.

Morawski, Z.J.R. 1971. *Hardwood survey in southern Ontario: Quality assessment interim report.* Toronto: Division of Forestry, Ontario Ministry of Natural Resources.

Morawski, Z.J.R., J.T. Basham and K.B. Turner. 1958. *Cull studies: A survey of a pathological condition in the forests of Ontario.* Report No. 25. Toronto: Forest Resources Inventory, Ontario Department Lands and Forests.

Morgenstern, E.K. 1979. *Genetics of deciduous species and spruces, Petawawa,1977-1978*. pp. 151-155. *In*: Proceedings of Seventeenth Canadian Tree Improvement Association Meeting, Part I, at Gander, Newfoundland C.W. Yeatman (ed.). Ottawa: Canadian Forest Service.

Morsink, W.A.G. and E. Jorgensen. 1974. *Propagation and selection of sugar maple* (Acer saccharum *Marsh.) in Ontario.* Toronto: Ontario Ministry of Natural Resources.

Moser, J.W., Jr., C.H. Tubbs and R.D. Jacobs. 1979. *Evaluation of a growth projection system for uneven-aged northern hardwoods*. Journal of Forestry 77: 421-423.

Murphy, R.J.K. *no date.(*a). *Crop tree pruning for better quality timber in Ontario*. Toronto: Timber Branch, Ontario Department Lands and Forests.

Murphy, R.J.K. *no date.(*b). *Upland tolerant hardwood management*. Toronto: Timber Branch, Ontario Department Lands and Forests.

Mutchmor, A.F. and A.E. Morneault. 1995. *Repeat prescribed burns for red oak regeneration*. *In*: Vegetation Management Alternatives Program 1994-1995 Annual Report. Sault Ste Marie, ON: Ontario Forest Research Institute. Ontario Ministry of Natural Resources. pp. 16-17.

Mutchmor, A.F. and B.D. Batchelor. 1996. *Mechanical Scarification to enhance natural red oak regeneration. In:* ONLINE to Central Ontario Science and Technology Developments, Winter 1996. Ontario Ministry of Natural Resources, Central Ontario Science and Technology Unit. North Bay, ON. pp. 25-28.

Myren, D.T. and E.B. Dorworth. 1986. *Names and authors used for fungi at the Great Lakes Forestry Centre.* Information Report O-X-376. Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Naylor, B. and L. Thompson (eds.). 1992. *Regenerating conifer cover in deer yards*. COFTDU Technical Report No. 28. Ontario Ministry of Natural Resources, Central Ontario Forest Technology Development Unit. North Bay, ON. 117 pp.

Naylor, B., S. Christilaw, A. Todd and C. Corbett. 1994. *Red-shouldered hawk habitat supply analysis for Bruton and Clyde Townships, Algonquin Park, 1990-2000*. CRST Technical Report No. 34. Ontario Ministry of Natural Resources, Central Region Science and Technology. North Bay, ON. 10 pp.

Naylor, B., S. Christilaw and P. Weilandt. 1992. *Validation of a habitat suitability index model for moose in the northern portion of the Great Lakes-St. Lawrence forest region of Ontario*. COFTDU Technical Report No. 26. Ontario Ministry of Natural Resources, Central Ontario Forest Technology Development Unit, North Bay, ON. 20 pp.

Naylor, B.J. 1994a. *Managing wildlife habitat in red pine and white pine forests of central Ontario*. Forestry Chronicle 70: 411-419.

Naylor, B.J. 1994b. *Habitat supply analysis: what it is, how it works and where we're going*. pp. 67-81 *In*: Forest Planning The Leading Edge. A.J. Kayll (ed.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute. Sault Ste Marie, ON.

Naylor, B.J. and P.G. Bush. *Spatial and nonspatial habitat suitability models for the pileated woodpecker in central Ontario*. SCST Technical Report (*in prep.*). North Bay, ON: Southcentral Science and Technology, Ontario Ministry of Natural Resources.

Naylor, B.J., J.A. Baker, D.M. Hogg, J.G. McNicol and W.R. Watt. 1996. *Forest management guidelines for the provision of pileated woodpecker habitat*. Sault Ste Marie, ON: Forest Management Branch, Ontario Ministry of Natural Resources. 26 pp.

Nyland, R. D. 1994. *Careful Logging in Northern Hardwoods.* pp. 29-52. *In*: Logging Damage: The Problems and Practical Solutions. J.A. Rice (ed.). Forest Research Report No. 117. Ontario Ministry of Natural Resources, Ontario Forest Research Institute. Toronto.

Nyland, R. D., P. J. Craul, D. F. Behrend, H. E. Echelberger, W. J. Gabriel, R. L. Nissen, R. Uebler and J. Zarnetske. 1976. *Logging and its effects in northern hardwood stands*. AFRI Research Report No. 31. Syracuse, NY: Applied Forest Research Institute, State University of New York, College of Environmental Science and Forestry. 134 pp.

Nyland, R.D. 1987. *Selection system and its application to uneven-aged northern hardwoods*. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002), 49-80. State University of New York, College of Environmental Science and Forestry. Syracuse, NY.

Nyland, R.D. and D.A. Marquis. 1978. *Appropriate silvicultural systems for northern hardwoods*. *In*: Proceedings of Joint Convention of Society of American Foresters and the Canadian Institute of Forestry. pp. 334-338. Society of American Foresters. Washington, DC.

Nyland, R.D. and W.J. Gabriel. 1971. *Logging damage to partially cut hardwood stands in New York State.* Research Report No. 5. Syracuse: Applied Forest Research Institute, State University of New York.

Nyland, R.D., (ed.). 1972. *A perspective on clearcutting in a changing world.* Research Report No. 4. Syracuse: Applied Forest Research Institute, State University of New York.

Nyland, R.D., L.P. Abrahamson and K.B. Adams. 1983. *Use of prescribed fire for regenerating red and white oak in New York*. pp. 163-167. *In*: Proceedings of Society of American Foresters Convention. Society of American Foresters. Washington, DC.

Nyland, R.D., P.J. Craul, D.F. Behrend, H.E. Echelberger, W.J. Gabriel, R.L. Nissen, Jr., R. Uebler and J. Zametske. 1976. *Logging and its effects in northern hardwoods.* Research Report No. 31. Syracuse: Applied Forest Research Institute, State University of New York.

Olson, J.T., A.L. Lundgren and D. Rose. 1978. *Equations for estimating stand establishment, release and thinning costs in the Lake States.* Research Paper NC-163. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

OMAF. 1988. *Guide to chemical weed control.* Publication No. 75. Toronto: Ontario Ministry of Agriculture and Food.

OMNR. 1995. *Policy framework for sustainable forests.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1994. *A conservation strategy for old growth red and white pine forest ecosystems for Ontario.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1973. *Management of tolerant hardwoods in Algonquin Provincial Park.* Toronto: Forest Management Branch, Ontario Ministry of Natural Resources.

OMNR. 1977. *The planting of hardwood trees and shrubs.* Toronto: Forest Management Branch, Ontario Ministry of Natural Resources.

OMNR. 1983. *Management of tolerant hardwoods in Algonquin Provincial Park.* Toronto: Forest Resources Branch, Ontario Ministry of Natural Resources.

OMNR. 1986a. *Draft guidelines for providing furbearer habitat in timber management.* Unpublished. Report. Toronto: Wildlife Branch, Ontario Ministry of Natural Resources. 31 pp.

OMNR. 1986b. *Guidelines for tree seed crop forecasting and collecting.* Toronto: Forest Resources Branch, Ontario Ministry of Natural Resources.

OMNR. 1986c. *Ontario forest industry statistical reports for 1985.* Toronto: Timber Sales Branch, Ontario Ministry of Natural Resources.

OMNR. 1986d. *The forest resources of Ontario 1986.* Toronto: Forest Resources Branch, Ontario Ministry of Natural Resources.

OMNR. 1986e. *The logger's pocketbook.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1986f. *Timber management planning manual for Crown lands in Ontario.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1986g. *The forest management challenge*. Toronto: Forest Resources Group, Ontario Ministry of Natural Resources.

OMNR. 1987a. *Peregrine falcon habitat management guidelines*. Unpublished Report. Toronto: Wildlife Branch, Ontario Ministry of Natural Resources. 9 pp.

OMNR. 1987b. *Bald eagle habitat management guidelines*. . Unpublished Report. Toronto: Wildlife Branch, Ontario Ministry of Natural Resources. 18+pp.

OMNR. 1987c. *Prescribed burn planning manual for Crown lands in Ontario.* Toronto: Forest Resources Group, Ontario Ministry of Natural Resources.

OMNR. 1987d. *Tree improvement master plan for Ontario.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1987e. *Statistics 1987.* Toronto: Forest Resources Group, Ontario Ministry of Natural Resources.

OMNR. 1987f. *Timber management guidelines for providing white-tailed deer habitat.* Toronto: Wildlife Branch, Ontario Ministry of Natural Resources.

OMNR. 1987i. *Timber management guidelines for the protection of tourism values.* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1988a. *Timber management guidelines for the provision of moose habitat*. Toronto: Wildlife Branch, Ontario Ministry of Natural Resources. 33 pp.

OMNR. 1988b. *Timber management guidelines for the protection of fish habitat*. Toronto: Fisheries Branch, Ontario Ministry of Natural Resources. 14 pp.

OMNR, 1988c *Environmental Guidelines for Access Roads and Water Crossings* Toronto: Ontario Ministry of Natural Resources.

OMNR. 1991. *Code of practice for timber management operations in riparian areas*. Sault Ste Marie, ON: Forest Management Branch, Ontario Ministry of Natural Resources. 9 pp.

OMNR. 1991b *Statistics 1989-1990* Toronto: Ontario Ministry of Natural Resources

OMNR. 1996a. *Forest Management Planning Manual for Ontario's Crown Forests*. Toronto: Queen's Printer for Ontario. 452 pp.

OMNR. 1996b. *Prescribed Burn Planning Manual (in press)*. AFFMB Publication No. 313. Ontario Ministry of Natural Resources.

OMNR. 1996c. *Forest Resources of Ontario* Toronto: Ontario Ministry of Natural Resources

OMNR. 1998 (draft). *Southern Ontario Silvicultural Guide*, OMNR Southcentral Science Section.

OMNR. *Environmental guidelines*. (*in prep.*). Sault Ste Marie, ON: Forest Management Branch, Ontario Ministry of Natural Resources.

Ondro, W.J. and D.V. Love. 1979. *Growth response of northern hardwoods to partial cutting in southern Ontario*. Forestry Chronicle 55: 13-16.

Ontario Centre for Soil Resource Evaluation. 1995 *Field Manual for Describing Soils in Ontario*

Ontario Weed Committee. 1995. *Guide to weed control*. Publication. 75. Food and Rural Affairs. Ontario Ministry of Agriculture and Food. 208 pp.

Ontario Wildlife Working Group. 1991. *Looking ahead: a wild life strategy for Ontario*. Toronto: Wildlife Policy Branch, Ontario Ministry of Natural Resources. 172 pp.

Ostrander, M.D. 1965. *A guide to hardwood log grading.* Revised edition. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Otchere-Boateng, J. and G. Ackerman. 1990. *A guide to vegetation control equipment*. FRDA Handbook 005. Victoria, BC. British Columbia Ministry of Forests.

Peck, G.K. and R.D. James. 1987. *Breeding birds of Ontario: nidiology and distribution (Vol. 2). Passerines*. Life Science Misc. Publication. Toronto: Royal Ontario Museum. 387 pp.

Penak, B. 1983. *Management guidelines and recommendations for osprey in Ontario*. (Unpublished Report. Toronto: Wildlife Branch, Ontario Ministry of Natural Resources. 32 pp.

Perala, D.A. 1974. *Growth and survival of northern hardwood sprouts after burning.* Research Note NC-176. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Petro, F.J. 1962. *How to evaluate the quality of hardwood logs for factory lumber.* Technical Note No. 34. Ottawa: Forest Products Research Branch, Canadian Department of Forestry.

Philip, M.S., 1994. *Measuring trees and forests*. 2nd edition. Wallingford, U.K. CAP International. 310 pp.

Pierpoint, G. 1986. *An orientation to site classification in Ontario*. pp. 24-28. *In*: Proceedings of Site Classification in Relation to Forest Management Symposium. Canada-Ontario Joint Forest Research Committee (*comp*.). Publication O-P-14. Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Pierpoint, G. and P. Uhlig. 1985. *Catalogue of land resource surveys in Ontario of major value in forest management.* Toronto: Ontario Ministry of Natural Resources.

Pinto, F., C. Nelson, B. Naylor and R. White. 1996. *Regeneration planning and prescriptions* (unpublished). 20 pp. *In*: Regenerating Ontario's Forest. R. Wagner and S. Colombo (eds.). Ontario Ministry of Natural Resources, Forest Resources Branch. Sault Ste Marie, ON.

Pitel, J.A. and B.S.P. Wang 1988 *Improving germination of basswood* (Tilia americana *L.) with gibberellic acid.* Seed Science and Technical 16(1): 273-280.

Pitcher, J.A. 1982. *Phenotype selection and half-sib family performance in black cherry*. Forest Science 28: 251-256.

Plonski, W.L. 1960. *Normal yield tables for black spruce, jack pine, white birch, tolerant hardwoods, white pine and red pine*. Toronto: Ontario Department of Lands and Forests.

Plonski, W.L. 1974. Normal yield tables (metric) for major forest species of Ontario. Toronto: Forest Resources Group, Ontario Ministry of Natural Resources 40 pp.

Plonski, W.L. 1981. *Normal yield tables (metric) for major forest species of Ontario*. Toronto: Forest Resources Group, Ontario Ministry of Natural Resources.

Powell, D.S. and E.H. Tryon. 1979. *Sprouting ability of advance growth in undisturbed hardwood stands*. Canadian Journal of Forest Research 9: 116-120.

Province of Ontario. 1985. *Occupational health and safety act and regulations for industrial establishments.* Revised Statutes of Ontario, Chapter 321.

Province of Ontario. 1994. *Pesticides Act*. Revised Statutes of Ontario.

Pruitt, L.R. and S.E. Pruitt. 1987. *Effects of northern hardwood management on deer and other large mammal populations*. pp. 363-379 *In*: Managing Northern Hardwoods. R.D. Nyland (ed.). Publication No. 87-03. Society of American Foresters. Washington, DC.

Racey, G.D., A.G. Harris, J.K. Jeglum, R.F. Foster and G.M. Wickware.1996. Terrestrial and wetland ecosites of Northwestern Ontario. Ontario Ministry of Natural Resources, NWST Field Guide FG-02.

Rast, E.D. 1982. *Photographic guide of selected external defect indicators in northern red oak.* Research Paper NE-511. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Raymond, F.L. and M.M. McLean. 1984. *Simulation of growth and yield of hard maple*. Toronto: Timber Sales Branch, Ontario Ministry of Natural Resources.

Raymond, F.L. and M.M. McLean. 1987. *Simulation of growth and yield of hard maple (metric)*. Toronto: Timber Sales Branch, Ontario Ministry of Natural Resources.

Renken, R.B. and E.P. Wiggers. 1989. *Forest characteristics related to pileated woodpecker territory size in Missouri.* Condor 91: 642-652.

Rennolls, K. and P. Blackwell. 1986. *An integrated forest process model: Its calibration and predictive performance*. Paper No. 148. Edinborough, Scotland: Research and Development Branch, Forestry Commission (U.K.).

Rice, J.A., M.E. Woods and B.D. Batchelor. 1997 (*in press*). *SCANSS - Silvicultural calibration of Algoma/North Shore stands: A progress report*. Technical Report. Ontario Ministry of Natural Resources, South Central Science and Technology Unit.

Ripley, T.H. and R.A. Campbell. 1960. *Browsing and stand regeneration in clear- and selectively-cut hardwoods*. Transcripts of the North American Wildlife Conference 25: 407-415.

Roach, B.A. 1974. *Selection cutting and group selection.* Report No. 5. Syracuse: Applied Forest Research Institute, State University of New York.

Roach, B.A. 1977. *A stocking guide for Allegheny hardwoods and its use in controlling intermediate cuttings.* Research Paper NE-373. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Roach, B.A. and S.F. Gingrich. 1968. *Even-aged silviculture for upland central hardwoods.* Agriculture Handbook No. 355. Washington, DC: Forest Service, U.S. Department of Agriculture.

Roberge, M.R. 1977. *Influence of cutting methods on natural and artificial regeneration of yellow birch in Quebec northern hardwoods*. Canadian Journal of Forest Research 7: 175-182.

Rogers, L.L. and E.L. Lindquist. 1992. *Supercanopy white pine and wildlife*. pp. 39-43. *In*: White Pine Symposium Proceedings. R.A. Stine and M.J. Baughman. (eds.). Department of Forest Resources, University of Minnesota. St. Paul, MN.

Rogers, L.L., G.A. Wilker and A.W. Allen. 1988. *Managing northern forests for black bears*. pp. 39-43. *In*: Integrating Forest Management for Wildlife and Fish. General Technical Report NC-122. U.S. Department of Agriculture, Forest Service.

Rogers, R. 1980. *Evaluating stocking in upland hardwood forests using metric measurements.* Research Paper NC-187. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Rogers, R. and P.S. Johnson. 1982. *Is "COPPICE" a good predictor of red oak sprout growth?* pp. 185-192. *In*: Proceedings of Fourth Central Hardwoods Forest Conference at University of Kentucky. R.N. Muller (ed.).

Rogers, R. and P.S. Johnson. 1985. *Rule thinning: a field method for meeting stocking goals in oak stands*. pp. 106-110. *In*: Proceedings of Fifth Central Hardwoods Forest Conference at University of IL. J.O. Dawson and K.A. Majerus (eds.). Society of American Foresters Publication No. 85-05. Urbana-Champaign, IL: Department of Forestry, University of Illinois.

Roise, J.P. 1986. *An approach for optimizing residual diameter class distributions when thinning even-aged stands*. Forest Science 32: 871-81.

Roth, E.R. 1956. *Decay following thinning of sprout oak clumps*. Journal of Forestry 54*: 2*6-30.

Roth, R.R. 1976. *Spatial heterogeneity and bird species diversity*. Ecology 57: 773-782.

Roth, E.R. and G.H. Hepting 1943(a) *Origin and development of oak stump sprouts as affecting their likelihood to decay*. J. Forestry 41:27-36.

Roth, E.R. and G.H. Hepting 1943(b) *Wounds and decay caused by removing large companion sprouts of oaks.* Journal of Forest 41: 190-195.

Roth, E.R. and G.H. Hepting 1969 *Prediction of butt rot in newly regenerated sprout oak stands.* Journal of Forestry 67: 756-760.

Rowe, J.S. 1972. *Forest regions of Canada.* Publication No. 1300. Ottawa: Canadian Forest Service.

Rudolf, P.O. 1956. *Guide for selecting superior forest trees and stands in the Lake States.* Station Paper No. 40. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Runkle, J.R. 1979 *Gap phase dynamics in climax mesic forests.* PhD thesis, Cornell University, Ithaca, NY.

Runkle, J.R. 1981. *Gap regeneration in some old-growth forests of the eastern United States*. Ecology 62: 1041-1051.

Russell, T.E. 1971. *Seeding and planting upland oaks*. pp. 49-54. *In*: Proceedings of Oak Symposium a Morgantown, WV. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Sajdak, R.L. 1967. *Variation in bark characters and wood specific gravity in sugar maple*. pp. 10-14. *In*: Eighth Lake States Tree Improvement Conference. Research Paper NC-23. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Sander, I.L. 1977. *Manager's handbook for oaks in the North Central States.* General Technical Report NC-37. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Sander, I.L., P.S. Johnson and R. Rogers. 1984. *Evaluating oak advance reproduction in the Missouri Ozarks.* Research Paper NC-251. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Schlaegel, B.E. 1978. *Growth and yield of natural hardwood stands: Concepts, practices and problems.* pp. 120-129. *In*: Proceedings of Second Symposium on Southeastern Hardwoods.

Schlesinger, R.C., I.L. Sander and K.R. Davidson. 1993. *Evaluating oak advance reproduction in the Missouri Ozarks*. Research Paper NC-251. U.S. Department of Agriculture, Forest Service. North Central Forest Experiment Station. St. Paul, MN. 16 pp.

Schopmeyer, C.S. (tech. coord.) 1974 *Seeds of woody plants in the United States.* Agricultural. Handbook 450. U.S. Department of Agriculture, Forest Service, Washington, DC. 883 pp.

Shifley, S.R. 1982. *A preliminary comparison of three tree growth models for Central States species.* pp. 169-184. *In*: Proceedings of the Fourth Central Hardwoods Forest Conference at University of Kentucky. R.N. Muller (ed.).

Shifley, S.R. 1987. *A generalized system of models forecasting Central States tree growth*. Research Paper NC-279. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Shigo, A. L. 1966. *Decay and discoloration following logging wounds on northern hardwoods*. Research Paper NE-47. Upper Darby, PA: Northeast Forest Experimental Station, Forest Service, U.S. Department of Agriculture.

Shigo, A.L. 1965. *Decays and discolorations in northern hardwoods in the northeastern United States: a consideration of micro-organisms and external signs*. pp. 1-17. *In*: Proceedings of IUFRO Conference, Section 41.

Shigo, A.L. 1983. *Tree defects: a photo guide.* General Technical Report NE-82. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Shigo, A.L. 1984a. *How to assess the defect status of a stand*. Northern Journal of Applied Forestry 1: 41-49.

Shigo, A.L. 1984b. *Tree survival after injury and infection*. pp. 11-24. *In*: Proceedings of Eighth North American Foresters Biological Workshop at Logan, UT. R.M. Lunner (ed.). Logan, UT: Utah State University.

Shigo, A.L. and E.V. Larson. 1969. *A photo guide to the patterns of discoloration and decay in living northern hardwood trees.* Research Paper NE-127. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Silverborg, S.B. 1954. *Northern hardwoods cull manual.* Bulletin No. 31. Syracuse: College of Environmental Science and Forestry, State University of New York.

Simpson, Brian T., R. Peter Kollasch, Mark J. Twery and Thomas M. Schuler. 1995. *NED / SIPS user's manual: Northeast decision model stand inventory processor and simulator (Version 1.00)*. General Technical Report NE-205. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station. Radnor, PA. 103 pp.

Sims, R.A., H.M. Kershaw and G.M. Wickware. 1990. *The autecology of major tree species in the northcentral region of Ontario.* COFRDA Report 3302/NWOFTDU Technical Report 48. Sault Ste Marie, ON: Forestry Canada. Ontario Region. / Thunder Bay, ON: Northwestern Forest Technology Development Unit. Ontario Ministry of Natural Resources. 126 pp.

Sinclair, G.A. 1962. *Progress report of prescribed burning in hardwood stands in Ontario.* Forest Section Report No. 45. Toronto: Division of Research, Ontario Department Lands and Forests.

Skelly, J.M., D.D. David, W. Merrill, E.A. Cameron, H.D. Brown, D.B. Drummond and L.S. Dochinger, eds. 1987. *Diagnosing injury to eastern forest trees.* Atlanta: National Acid Precipitation Assessment Program, Forest Pest Management, U.S. Department of Agriculture.

Skilling, D.D. 1957. Is *the epicormic branching associated with hardwood pruning wounds influenced by tree crown class?* Technical Note No. 510. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Skilling, D.D. 1959a. *Pruning hardwoods improves quality and shows little evidence of fostering decay*. Timberman (May): 1-3.

Skilling, D.D. l959b. *Response of yellow birch to artificial pruning*. Journal of Forestry 57: 429-32.

Smalley, F.E. 1975. *Management of northern hardwood: A possible new approach*. Northern Logger and Timber Processor 24 (5): 10, 29-30.

Smith, C.R. 1981 (*with 1987 updates*). *Silvicultural equipment reference catalogue for southern Ontario.* Toronto: Forest Resources Branch, Ontario Ministry of Natural Resources.

Smith, C.R. 1987. *Review of current uses and trends in mechanized site preparation technology applicable to Ontario conditions*. pp. 31-39. *In*: Primeval Improvement: The New Forestry Age in Proceedings of Canada-Ontario Joint Forest Research Committee Symposium. Publication O-P-15. Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Smith, D.M. 1962. *The practice of silviculture.* 7th edition. New York: John Wiley & Sons. 578 pp.

Smith, D.M. 1986. *The practice of silviculture.* 8th edition. New York: John Wiley & Sons. 527 pp.

Smith, H.C. 1966. *Epicormic branching on eight species of Appalachian hardwoods.* Research Note NE-53. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Smith, H.C. 1983. *Growth of Appalachian hardwoods kept free to grow from 2 to 12 years after clearcutting.* Research Paper NE-528. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Smith, H.C. and N.I. Lamson. 1982. *Number of residual trees: A guide for selection cutting.* General Technical Report NE-80. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Smith, H.W., Jr. 1954a. *Tree grades as a silvicultural tool in the management of Cumberland Plateau hardwoods*. pp. 66-70. *In*: Proceedings of Society of American Foresters Convention. A.B. Meyer (ed.). Society of American Foresters. Washington, DC.

Smith, J.H.G. 1954b. *The economics of pruning*. Forestry Chronicle 30: 197-214.

Solomon, D.S., D.A. Herman and W.B. Leak. (*in press*). *FIBER 3.0: an ecological growth model for northeastern forest types*. General Technical Report. 73 pp.

Solomon, D.S. and B.M. Blum. 1967. *Stump sprouting of four northern hardwoods.* Research Paper NE-59. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Solomon, D.S. and W.B. Leak. 1969. *Stocking, growth and yield of birch stands*. pp. 106-118. *In*: Proceedings of Birch Symposium at Durham, NH. E. Larson (ed.). U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Solomon, D.S. and W.B. Leak. 1986. *Simulated yields for managed northern hardwood stands*. Research Paper NE-578. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Sonderman, D.L. 1979. *Guide to the measurement of tree characteristics important to the quality classification system for young hardwood trees.* Technical Report NE-54. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Sonderman, D.L. and R.L. Brisbin. 1978. *A quality classification system for young hardwood trees: The first step in predicting future products.* Research Paper NE-419. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Staley, R.L. 1991. *Woodlot Management and Plantation Improvement*. Ontario Ministry of Natural Resources.

Stayton, C.L. and R.M. Marden. 1970. *Is cull overestimated in northern hardwood stands?* Research Note NC-97. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Stayton, C.L., R.M. Marden and G.L. Gammon. 1971. *Predicting lumber grade yields for standing hardwood trees.* Research Paper NC-50. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Stayton, C.L., R.M. Marden and R.G. Buchman. 1970. *Exterior defect indicators and their associated interior defect in sugar maple*. Forest Products Journal 20: 55-58.

Stewart, R.E. 1978. *Site preparation*. pp. 100-129. *In:* Regenerating Oregon's Forests. B.D. Cleary, R.D. Greaves and R.K. Hermann (eds.). Corvallis, OR: School of Forestry, Oregon State University.

Stoeckeler, J.H. and C.F. Arbogast. 1947. *Thinning and pruning young second-growth hardwoods in northeastern Wisconsin*. pp. 328-346. *In*: Proceedings of Society of American Foresters Convention., H.L. Shirley (ed.). Society of American Foresters. Washington, DC.

Stout, S.L. 1987. *Planning the right residual: relative density, stand structure and species composition*. pp. 176-190. *In*: Proceedings of Managing Northern Hardwoods Silvicultural Symposium at Syracuse. R.D. Nyland (ed.). Publication No. 13 (ESF 87-002). Syracuse: College of Environmental Science and Forestry, State University of New York.

Stout, S.L., C.A. Nowak, D.S. deCalesta, T.M. Schuler, S.B. Jones and D.W. McGill. 1994. *Hardwood crop planning: Relative density guidelines for eastern Ontario hardwood stands*. Eastern Ontario Model Forest Information Report No. 12. 45 pp.

Stout, S.L. and R.D. Nyland. 1986. *Role of species composition in relative density measurements in Allegheny Hardwoods*. Canadian Journal of Forest Research, 16:574-579

Stribling, L.H., H.R. Smith and R.H. Yahner. 1990. *Bird community response to timber stand improvement and snag retention*. Northern Journal of Applied Forestry 7: 35-38.

Strickland, D. and R.J. Rutter. 1983. *Mammals of Algonquin Provincial Park.* Toronto: Wildlife Branch, Ontario Ministry of Natural Resources.

Stroempl, G. 1971 *Planting basswood is successful in hardwood cutovers.* Tree Planter's Notes 22:26-29.

Stroempl, G. 1965 *Germination of early collected fruit of* Tilia americana *L.* Resources Report 64. Ontario Department of Lands and Forests. Maple, ON. 22 pp.

Stroempl, G. 1983 (a). *Thinning clumps of northern hardwood stump sprouts to produce high quality timber.* Forest Research Information Paper No. 104. Ontario Ministry of Natural Resources, Ontario Tree Improvement and Forest Biomass Institute. Maple, ON.

Stroempl, G. 1983(b) *Growth response of basswood and sugar maple to an intermediate cutting.* Forest Resources Report 107. Ontario Ministry of Natural Resources. Maple, ON. 19 pp.

Stroempl, G. 1972 *Some ecological aspects of American basswood. In*: Proceedings of a Symposium on Southern Hardwoods. Ontario Department of Lands and Forests. Maple, ON. 15 pp. (mimeo).

Stroempl, G. 1986. *Red oak regeneration by planting and sowing after a prescribed burn in a shelterwood stand*. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources.

Stroempl, G. 1987a. *Growth and quality of red oak planted in a jack pine plantation.* Forest Research Note No. 44. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources.

Stroempl, G. 1987b. *Growth and quality of red oak planted in red pine plantation openings.* Forest Research Report No. 117. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources.

Sutherland, B.J. and F. F. Foreman. 1995 *Guide to the use of mechanical site preparation equipment in northwestern Ontario.* Sault Ste Marie ON: Canadian Forest Service

Sutherland, B.J. 1986. *Standard assessment procedures for evaluating silvicultural equipment: A handbook.* Sault Ste Marie, ON: Great Lakes Forest Research Centre., Canadian Forest Service.

Sutton, R.F. 1985. *Vegetation management in Canadian forestry.* Information Report O-X-369. Ottawa: Canadian Forest Service.

Sykes, J.M. 1964. *Report on the interim results of prescribed spring burning in a poor quality hardwood stand.* Forest Section Report No. 49. Toronto: Division of Research, Ontario Department Lands and Forests.

Szuba, K. and P. Bell. 1991. *Hawk guide*. Unpublished Report. Toronto: Wildlife Policy Branch, Ontario Ministry of Natural Resources. 44 pp.

Szuba, K.J., B.J. Naylor and J.A. Baker. 1992a. *Nesting habitat of red-shouldered hawks in the Great Lakes-St. Lawrence forest region of central and southeastern Ontario*. COFTDU Technical Report No. 14. North Bay, ON: Central Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources. 24 pp.

Szuba, K.J., B.J. Naylor and J.A. Baker. 1992b. *A habitat suitability index model for red-shouldered hawks in the St. Laurent Ecoregion of south-eastern Ontario*. COFTDU Technical Report No. 24. North Bay, ON: Central Ontario Forest Technology Development Unit, Ontario Ministry of Natural Resources. 27 pp.

Taylor, E.P. 1981. *The relationship between the soils and forest tree species of southern Ontario (Site region 6E and 7E): A literature review.* Guelph, ON: Ontario Institute of Pedology.

Taylor, E.P. 1986. *Soil interpretation and training program for the Central and Southwestern regions 1980-1985*. pp. 135-142. *In*: Proceedings of Site Classification in Relation to Forest Management Symposium. Canada-Ontario Joint Forest Research Committee (*comp.*) Publication O-P-14. Canadian Forest Service, Great Lakes Forest Research Centre. Sault Ste Marie, ON.

Taylor, E.P. and P.K. Jones. 1986. *Soil interpretation and training for forestry 1981-1985 in the Central and Southwestern Regions, Site region 6E and 7E.* Guelph, ON: Ontario Institute of Pedology.

Teclaw, R.M. and J.G. Isebrands. 1986. *Collection procedures affect germination of northern red oak (*Quercus rubra *L.*) acorns. Tree Planters' Notes 37: 8-12.

Treidl, R.A. 1978. *Handbook on agricultural and forest meteorology.* Ottawa: Canadian Forest Service.

Trimble, G.R. Jr. and D.W. Seegrist. 1973. *Epicormic branching on hardwood trees bordering forest openings.* Research Paper NE-261. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R. Jr. and G. Hart. 1961. *An appraisal of early reproduction after cutting in northern Appalachian hardwood stands.* Station Paper No. 162. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R. Jr. and J.J. Mendel. 1969. *The rate of value increase for northern red oak, white oak and chestnut oak.* Research Paper NE-129. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1960. *Relative diameter growth rates of five upland oaks in West Virginia*. Journal of Forestry 58: 111-15.

Trimble, G.R., Jr. 1963. *Cull development under all-aged management of hardwood stands.* Research Paper NE-10. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1965a. *Reducing the proportion of cull material in hardwood stands*. Northern Logger, (August).

Trimble, G.R., Jr. 1965b. *Species composition changes under individual tree selection cutting in cove hardwoods.* Research Note NE-30. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1969. *Diameter growth of individual hardwood trees: The effect of certain tree and environmental factors on the growth of several species.* Research Paper NE-145. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1973. *The regeneration of Central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practice.* Research Paper NE-282. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1974. *Response to crop tree release by 7-year-old stems of red maple stump sprouts and northern red oak advance reproduction.* Research Paper NE-303. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. 1975. *Summaries of some silvical characteristics of several Appalachian hardwood trees.* General Technical Report NE-16. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. and G.W. Wendel. 1963. *Cost of marking hardwood sawtimber in West Virginia.* Research Note NE-15. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr. and H.C. Smith. 1963. *What happens to living cull trees left after heavy cutting in mixed hardwood stands?* Research Note NE-12. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Trimble, G.R., Jr., J.J. Mendel and R.A. Kennell. 1974. *A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines.* Research Paper NE-292. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Tubbs, C.H. 1965. *Influence of temperature and early spring condition on sugar maple and yellow birch germination in Upper Michigan.* Research Note LS-72 U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Tubbs, C.H. 1977. *Manager's handbook for northern hardwoods in the north central states*. General Technical Report NC-39. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Tubbs, C.H. 1977a. *Natural regeneration of northern hardwoods in the northern Great Lakes region.* Research Paper NC-150. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Tubbs, C.H. 1977b. *Manager's handbook for northern hardwoods in the North Central States.* General Technical Report NC-39. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Tubbs, C.H. and R.R. Oberg. 1978. *How to calculate size-class distribution for all-aged forests.* U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. St. Paul, MN.

Tubbs, C.H., D.M. DeGraaf, M. Yamasaki and W.M. Healy. 1987. *Guide to wildlife tree management in New England northern hardwoods.* General Technical Report NE-118. Forest Service, U.S. Department of Agriculture. 30 pp.

Tubbs, C.H., R.D. Jacobs and D. Cutler. 1983. *Northern hardwoods*. pp. 121-127. *In*: Silvicultural Systems for the Major Forest Types of the United States. Agriculture Handbook No. 44. U.S. Department of Agriculture, Forest Service. Washington, DC.

Van Wagner, C.E. 1978. *Age-class distribution and the forest fire cycle*. Canadian Journal of Forest Research. 8: 220-227.

Van Wagner, C.E. 1993. *Prescribed fire in the Great Lakes - St. Lawrence and deciduous forests of Ontario*. CRSTDU Technical Report No. 23. North Bay, ON: Central Region Science and Technology, Ontario Ministry of Natural Resources. 68 pp.

Vanclay, J.K. 1988. *A stand growth model for cypress pine*. pp. 310-332. *In*: Modeling Trees, Stands and Forests—Proceedings of a Workshop, August 1985. Bulletin No. 5. J.W. Leech, R.E. McMurtrie, P.W. West, R.D. Spencer and B.M. Spencer (eds.). University of Melbourne, School of Forestry. Melbourne, Australia.

Vanclay, K.J. 1994. *Modeling forest growth and yield. Applications to mixed tropical forests*. Oxon, UK: CAB International. 312 pp.

Vanclay, K.J. and N.B. Henry. 1988. *Assessing site productivity of indigenous cypress pine forest in southern Queensland*. Commonwealth Forestry Review 67: 53-64.

Verme, L.J. 1965. *Swamp conifer deer yards in northern Michigan: their ecology and management.* Journal of Forestry. 63: 523-529.

Voigt, D.R., J.D. Broadfoot and J.A. Baker. 1997. *Forest management guidelines for the provision of white-tailed deer habitat.* Ontario Ministry of Natural Resources, Forest Management Branch, Sault Ste Marie. 33 pp.

Von Althen, F.W. 1974. *Methods for the successful establishment of black cherry plantations in southern Ontario.* Information Report O-X-205. Ottawa: Canadian Forest Service.

Von Althen, F.W. 1979a. *Planting and tending recommendations for red oak.* Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Von Althen, F.W. 1979b. *Planting and tending recommendations for white ash.* Sault Ste Marie, ON: Great Lakes Forest Research Centre, Canadian Forest Service.

Von Althen, F.W. *no date.(* A *guide to hardwood planting on abandoned farmland in southern Ontario.* Sault Ste Marie, ON: Great Lakes Forest Research Centre., Canadian Forest Service.

Von Althen, F.W. and D.P. Webb. 1980. *Planting sugar maple on abandoned farmland in southern Ontario*. pp. 354-373. *In*: Proceedings of Third Central Hardwoods Forest Conference at University of Missouri. H.E. Garrett and G.S. Cox (eds.). Columbia: University of Missouri.

Waldron, R.M. 1973. *Direct seeding in Canada: 1900-1972*. *In*: Proceedings of Direct Seeding Symposium at Timmins, ON. J.H. Cayford (ed.). Publication No. 1339, 11-27. Ottawa: Canadian Forest Service.

Ward, W.W. 1964. *Live crown ratio and stand density in young, even-aged red oak stands*. Forest Science 10: 56-65.

Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol and B.J. Naylor. 1996. *Forest management guidelines for the provision of marten habitat*. Sault Ste Marie, ON: Forest Management Branch, Ontario Ministry of Natural Resources. 27 pp.

Wearn, V.H., E.A. Springer and A. Lesage. 1982. *Forest manager's photo guide to prescribed burn planning.* Kapuskasing, ON: Ontario Ministry of Natural Resources.

Wearstler, K.A. Jr. and B.V. Barnes. 1977. *Genetic diversity of yellow birch seedlings in Michigan*. Canadian Journal of Botany 55: 2778-88.

Weitzman, S. and G.R. Trimble, Jr. 1957. *Some natural factors that govern the management of oaks.* Station Paper No. 88. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Wendel, G.W. 1975. *Stump sprout growth and quality of several Appalachian hardwood species after clearcutting.* Research Paper NE-329. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Wendel, G.W. and N.I. Lamson. 1987. *Effects of herbicide release on the growth of 8- to 12-year-old hardwood crop trees.* Research Paper NE-598. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station, Upper Darby, PA.

Whitlaw, H., B. Naylor and T. Bellhouse. 1993. *The influence of residual stocking and time since harvest on winter browse supply for white-tailed deer*. CRST Technical Report No. 32. North Bay, ON: Central Region Science and Technology, Ontario Ministry of Natural Resources. 8 pp.

Whitney, G.G. 1986. *Relation of Michigan's presettlement pine forests to substrate and disturbance history.* Ecology 67: 1548-1559.

Wilcox, H., F. Czabator and G. Girolami. 1954. *Seasonal variations in bark-peeling characteristics of some Adirondack pulpwood species.* Journal of Forestry 52 (5): 338-342.

Williams, J.R.M. 1965. *A study of potential productivity in Ontario*. Paper presented at the Northeast Forest Soils Conference at Simcoe, ON.

Williamson, D.R. and P.B. Lane. 1989. *The use of herbicides in the forest. 3rd edition*. Forestry Commission Field Book 8. Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. U.K. Forestry Commission.

Wilton, M.L. and D.L. Garner. 1991. *Preliminary findings regarding elevation as a major factor in moose calving site selection in south central Ontario, Canada*. Alces 27: 111-117.

Wilusz, W. and M. Giertych. 1974. *Effects of classical silviculture on the genetic quality of the progeny*. Silvae Genetica 23, 4: 127-30.

Winget, C.H. 1968 *Species composition and development of second-growth Hardwood stands in Quebec.* Forestry Chronicle 44: 31-35.

Woods, K.D. and R.H. Whittaker 1981 *Canopy-understory interaction and the internal dynamics of mature hardwood and hemlock-hardwood forests*. pp. 305-323. *In*: Forest Succession - Concepts and Application. D.C. West, H.H. Shugart and D.B. Botkin (eds.). Springer-Verlag, NY.

Wright, J.W. 1944. *Genotypic variation in white ash*. Journal of Forestry 42: 489-495.

Zillgitt, W.M. 1949. *Basal area in merchantable trees as an expression of stocking in northern hardwoods.* Technical Note No. 324. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. St. Paul, MN.

Zillgitt, W.M. and S.R. Gevorkiantz. 1948. *Estimating cull in northern hardwoods with special reference to sugar maple*. Journal of Forestry 46: 588-94.

Zobel, B. and J. Talbert. 1984. *Applied forest tree improvement.* New York: John Wiley & Sons.

Zoltai, S.N. 1986. *Ecoclimatic regions of Canada*. Maple, ON: Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources. Photocopy.

APPENDIX A

Tree Species Abbreviations

Tree 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

From: OMNR. 1990. *Silvicultural information system manual*. Toronto: Queen's Printer for Ontario. pp. 12-16, Section 6. OMNR Document Number 5412.

APPENDIX B

Ecosite Fact Sheet
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 C

Form Class 79 Volume Table

Form Class 79 Volume Table

Form Class 79

DBH	Merchantable Length (m)																		
(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	0.0392	0.0588	0.0784	0.0980	0.1169	0.1343	0.1503	0.1649	0.1782	0.1922	0.2035	0.2137	0.2226	0.2304	0.2471	0.2537	0.2591	0.2634	0.2665
22	0.0474	0.0712	0.0949	0.1186	0.1415	0.1626	0.1821	0.2000	0.2163	0.2341	0.2484	0.2612	0.2727	0.2828	0.3029	0.3116	0.3189	0.3248	0.3294
24	0.0565	0.0847	0.1129	0.1412	0.1684	0.1937	0.2170	0.2384	0.2581	0.2802	0.2977	0.3136	0.3279	0.3406	0.3644	0.3755	0.3849	0.3927	0.3991
26	0.0663	0.9940	0.1325	0.1657	0.1977	0.2274	0.2549	0.2802	0.3035	0.3304	0.3515	0.3707	0.3881	0.4038	0.4315	0.4453	0.4571	0.4672	0.4755
28	0.7690	0.1153	0.1537	0.1921	0.2292	0.2637	0.2958	0.3253	0.3525	0.3847	0.4097	0.4325	0.4534	0.4724	0.5043	0.5210	0.5356	0.5481	0.5587
30	0.0882	0.1323	0.1765	0.2206	0.2632	0.3029	0.3398	0.3739	0.4053	0.4432	0.4724	0.4993	0.5240	0.5465	0.5793	0.5987	0.6158	0.6309	0.6439
32	0.1004	0.1506	0.2008	0.2510	0.2996	0.3449	0.3871	0.4263	0.4625	0.5059	0.5396	0.5708	0.5996	0.6259	0.6671	0.6906	0.7114	0.7297	0.7456
34	0.1133	0.1700	0.2267	0.2833	0.3382	0.3896	0.4376	0.4822	0.5237	0.5726	0.6112	0.6470	0.6802	0.7107	0.7570	0.7843	0.8087	0.8303	0.8491
36	0.1271	0.1906	0.2541	0.3176	0.3792	0.4370	0.4911	0.5415	0.5884	0.6435	0.6873	0.7281	0.7659	0.8009	0.8533	0.8848	0.9130	0.9382	0.9604
38	0.1416	0.2123	0.2831	0.3539	0.4225	0.4870	0.5473	0.6037	0.6561	0.7185	0.7679	0.8140	0.8569	0.8966	0.9581	0.9943	1.0270	1.0563	1.0824
40	0.1569	0.2353	0.3137	0.3921	0.4682	0.5396	0.6066	0.6691	0.7274	0.7976	0.8526	0.9039	0.9515	0.9956	1.0690	1.1103	1.1477	1.1814	1.2116
42	0.1729	0.2594	0.3459	0.4323	0.5162	0.5952	0.6693	0.7386	0.8033	0.8810	0.9424	1.0000	1.0539	1.1041	1.1833	1.2297	1.2719	1.3102	1.3446
44	0.1898	0.2847	0.3796	0.4745	0.5667	0.6536	0.7352	0.8117	0.8833	0.9685	1.0365	1.1003	1.1601	1.2160	1.3023	1.3540	1.4012	1.4441	1.4829
46	0.2074	0.3112	0.4149	0.5186	0.6194	0.7146	0.8042	0.8883	0.9671	1.0600	1.1349	1.2053	1.2714	1.3332	1.4269	1.4841	1.5366	1.5844	1.6278
48	0.2259	0.3388	0.4517	0.5647	0.6746	0.7784	0.8763	0.9683	1.0547	1.1558	1.2379	1.3152	1.3878	1.4559	1.5572	1.6202	1.6779	1.7307	1.7786
50	0.2451	0.3676	0.4902	0.6127	0.7320	0.8448	0.9514	1.0518	1.1461	1.2556	1.3452	1.4297	1.5093	1.5839	1.6931	1.7621	1.8255	1.8834	1.9360
52	0.2651	0.3976	0.5302	0.6627	0.7918	0.9141	1.0296	1.1387	1.2413	1.3596	1.4571	1.5491	1.6359	1.7174	1.8366	1.9119	1.9813	2.0448	2.1027
54	0.2859	0.4288	0.5717	0.7147	0.8540	0.9860	1.1110	1.2291	1.3404	1.4678	1.5734	1.6733	1.7676	1.8564	1.9872	2.0692	2.1449	2.2144	2.2779
56	0.3074	0.4612	0.6149	0.7686	0.9185	1.0607	1.1955	1.3229	1.4431	1.5803	1.6945	1.8026	1.9048	2.0011	2.1436	2.2327	2.3150	2.3907	2.4602
58	0.3298	0.4947	0.6596	0.8245	0.9853	1.1381	1.2830	1.4202	1.5498	1.6990	1.8225	1.9394	2.0499	2.1540	2.3007	2.3964	2.4851	2.5669	2.6420
60	0.3529	0.5294	0.7058	0.8823	1.0545	1.2182	1.3736	1.5209	1.6601	1.8220	1.9552	2.0812	2.2003	2.3126	2.4632	2.5659	26612	2.7493	2.8302
62	0.3768	0.5653	0.7537	0.9421	1.1260	1.3010	1.4673	1.6250	1.7743	1.9481	2.0910	2.2264	2.3544	2.4751	2.6353	2.7459	2.8486	2.9436	3.0313
64	0.4015	0.6023	0.8031	1.0039	1.1999	1.3866	1.5642	1.7327	1.8924	2.0772	2.2300	2.3748	2.5119	2.6413	2.8174	2.9367	3.0477	3.1507	3.2457
66	0.4270	0.6406	0.8541	1.0676	1.2762	1.4749	1.6640	1.8437	2.0141	2.2103	2.3734	2.5280	2.6745	2.8129	3.0056	3.1339	3.2536	3.3647	3.4675
68	0.4533	0.6800	0.9066	1.1333	1.3548	1.5660	1.7671	1.9583	2.1397	2.3504	2.5245	2.6896	2.8460	2.9938	3.1936	3.3306	3.4585	3.5775	3.6878
70	0.4804	0.7205	0.9607	1.2009	1.4356	1.6597	1.8731	2.0762	2.2691	2.4946	2.6801	2.8561	3.0228	3.1802	3.3871	3.5332	3.6696	3.7968	3.9148
72	0.5082	0.7623	1.0164	1.2705	1.5189	1.7561	1.9823	2.1976	2.4023	2.6418	2.8388	3.0258	3.2029	3.3703	3.5864	3.7417	3.8868	4.0222	4.1480
74	0.5368	0.8052	1.0737	1.3421	1.6046	1.8554	2.0946	2.3225	2.5393	2.7918	3.0004	3.1985	3.3862	3.5639	3.7914	3.9560	4.1099	4.2535	4.3869
76	0.5662	0.8494	1.1325	1.4156	1.6925	1.9573	2.2099	2.4508	2.6801	2.9459	3.1664	3.3759	3.5746	3.7628	4.0020	4.1762	4.3392	4.4912	4.6325
78	0.5964	0.8947	1.1929	1.4911	1.7829	2.0619	2.3284	2.5826	2.8247	3.1070	3.3405	3.5625	3.7733	3.9730	4.2277	4.4134	4.5873	4.7497	4.9009
80	0.6274	0.9411	1.2548	1.5685	1.8755	2.1692	2.4499	2.7178	2.9730	3.2726	3.5196	3.7546	3.9778	4.1896	4.4605	4.6583	4.8437	5.0171	5.1787
82	0.6592	0.9888	1.3184	1.6479	1.9705	2.2793	2.5746	2.8565	3.1252	3.4413	3.7018	3.9500	4.1859	4.4098	4.6974	4.9072	5.1040	5.2883	5.4602
84	0.6917	1.0376	1.3835	1.7293	2.0679	2.3922	2.7023	2.9986	3.2813	3.6123	3.8864	4.1477	4.3966	4.6331	4.9347	5.1562	5.3641	5.5586	5.7403
86	0.7251	1.0876	1.4501	1.8126	2.1676	2.5077	2.8332	3.1442	3.4410	3.7873	4.0753	4.3503	4.6124	4.8619	5.1779	5.4113	5.6305	5.8357	6.0272
88	0.7592	1.1388	1.5183	1.8979	2.2698	2.6264	2.9680	3.2949	3.6072	3.9698	4.2726	4.5620	4.8380	5.1010	5.4310	5.6771	5.9082	6.1248	6.3272
90	0.7941	1.1911	1.5881	1.9852	2.3743	2.7479	3.1060	3.4490	3.7771	4.1569	4.4751	4.7792	5.0694	5.3461	5.6913	5.9503	6.1938	6.4222	6.6358
92	0.8298	1.2446	1.6595	2.0744	2.4812	2.8719	3.2468	3.6061	3.9500	4.3482	4.6822	5.0016	5.3067	5.5977	5.9561	6.2283	6.4846	6.7252	6.9506
94	0.8662	1.2993	1.7325	2.1656	2.5903	2.9984	3.3900	3.7656	4.1252	4.5440	4.8944	5.2298	5.5506	5.8569	6.2232	6.5093	6.7790	7.0328	7.2707
96	0.9035	1.3552	1.8070	2.2587	2.7017	3.1275	3.5364	3.9285	4.3041	4.7441	5.1112	5.4631	5.7999	6.1219	6.4961	6.7965	7.0800	7.3471	7.5981
98	0.9415	1.4123	1.8830	2.3538	2.8156	3.2598	3.6866	4.0962	4.4889	4.9452	5.3287	5.6965	6.0489	6.3862	6.7786	7.0933	7.3909	7.6716	7.9359
100	0.9803	1.4705	1.9607	2.4508	2.9319	3.3949	3.8401	4.2679	4.6783	5.1497	5.5495	5.9334	6.3016	6.6543	7.0690	7.3987	7.7108	8.0056	8.2835

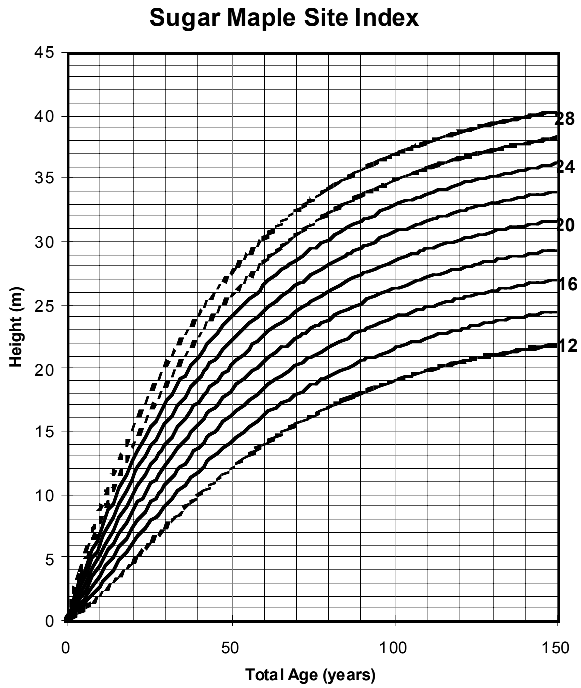
Source: Appendix C "Sugar Bush Management for Maple Syrup Production", 1987, C.Coons

APPENDIX D

Hardwood Species Factsheets

Sugar Maple Growth & Yield Factsheet

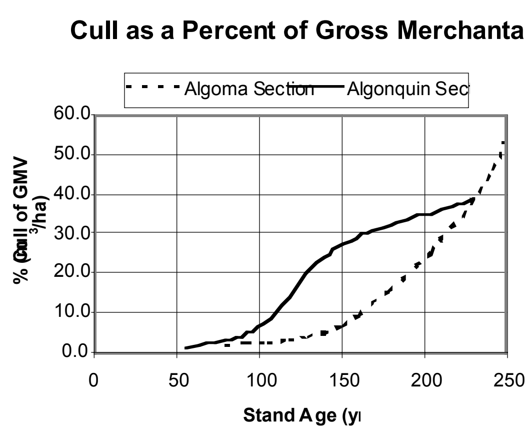
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.78	1.14	1.55	2.01	2.51	3.04	3.61	4.21	4.84
10	1.97	2.67	3.42	4.23	5.07	5.95	6.85	7.78	8.73
15	3.30	4.29	5.32	6.40	7.50	8.63	9.78	10.94	12.11
20	4.67	5.90	7.17	8.46	9.77	11.09	12.42	13.76	15.09
25	6.02	7.46	8.92	10.39	11.87	13.34	14.82	16.29	17.76
30	7.34	8.95	10.57	12.18	13.79	15.40	16.99	18.57	20.14
35	8.60	10.36	12.11	13.84	15.56	17.27	18.95	20.62	22.28
40	9.79	11.68	13.54	15.37	17.18	18.97	20.74	22.48	24.20
45	10.92	12.90	14.86	16.78	18.67	20.52	22.35	24.15	25.93
50	11.97	14.04	16.07	18.07	20.02	21.93	23.82	25.67	27.49
55	12.94	15.10	17.19	19.24	21.25	23.22	25.14	27.04	28.90
60	13.85	16.07	18.22	20.32	22.37	24.38	26.35	28.28	30.17
65	14.69	16.96	19.16	21.31	23.40	25.44	27.44	29.40	31.32
70	15.46	17.78	20.02	22.21	24.33	26.40	28.43	30.41	32.36
75	16.17	18.53	20.81	23.03	25.18	27.28	29.33	31.33	33.30
80	16.82	19.22	21.53	23.77	25.95	28.07	30.14	32.16	34.15
85	17.42	19.85	22.19	24.45	26.65	28.79	30.88	32.92	34.92
90	17.97	20.43	22.79	25.07	27.29	29.44	31.55	33.60	35.61
95	18.48	20.95	23.33	25.63	27.87	30.04	32.15	34.22	36.25
100	18.93	21.43	23.83	26.15	28.39	30.58	32.71	34.78	36.82
105	19.35	21.87	24.28	26.61	28.87	31.07	33.20	35.29	37.33
110	19.74	22.27	24.69	27.04	29.31	31.51	33.66	35.75	37.80
115	20.09	22.63	25.07	27.42	29.70	31.91	34.07	36.17	38.23
120	20.41	22.96	25.41	27.77	30.06	32.28	34.44	36.55	38.61
125	20.70	23.26	25.72	28.09	30.38	32.61	34.78	36.89	38.96
130	20.96	23.53	26.00	28.38	30.68	32.91	35.09	37.21	39.28
135	21.20	23.78	26.26	28.64	30.95	33.18	35.36	37.49	39.56
140	21.42	24.01	26.49	28.88	31.19	33.43	35.62	37.74	39.82
145	21.62	24.21	26.70	29.09	31.41	33.66	35.84	37.98	40.06
150	21.80	24.40	26.89	29.29	31.61	33.86	36.05	38.19	40.27

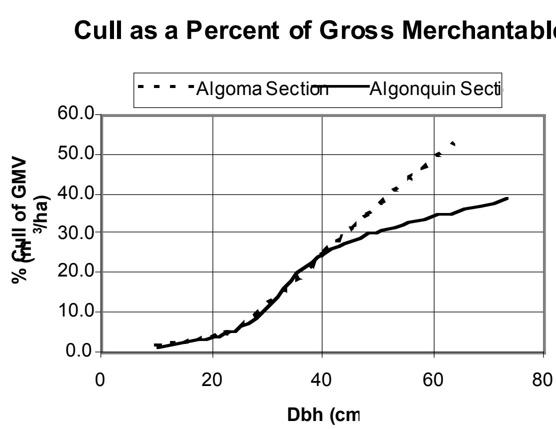


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*3.048^{b5})}]*3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.1308	0.6904	-0.0195	10.1563	-0.5330	0.99	0.38	1.6
SI	0.1984	1.2089	-0.0110	-2.4917	-0.2542	0.98	0.58	2.0

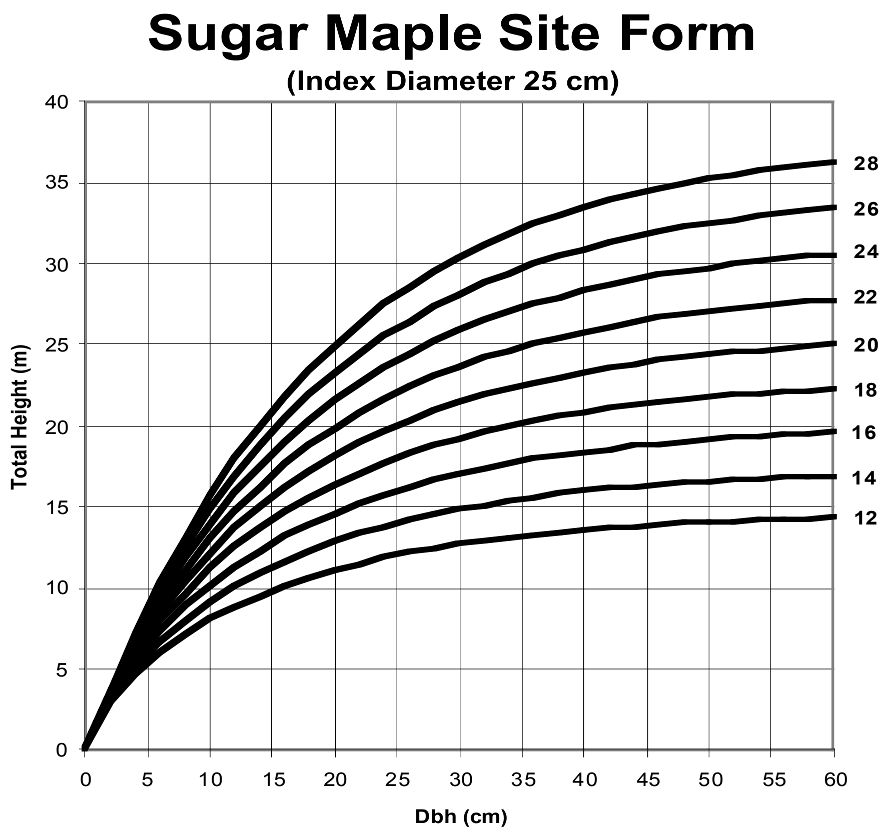
Data Source: *Carmean 1978.* *Northwest Wisconsin and Upper Michigan.* *177 plots having 721 dominant and codominant trees.*
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***





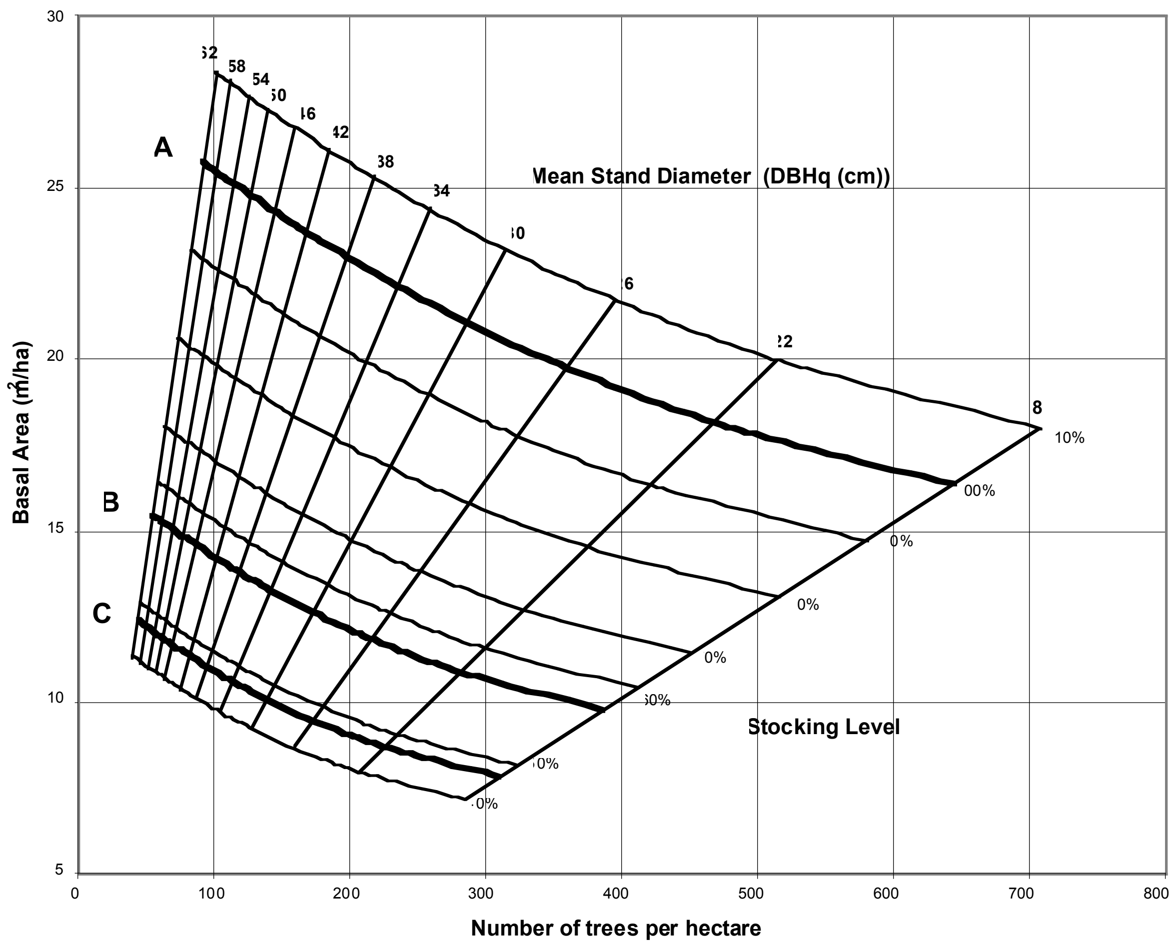
Data Source:Morawski, Z.J.R. 1978 3922 Trees

Sugar Maple Site Form



Dbh (cm)	Site Form 12	14	16	18	20	22	24	26	28
2	3.0	3.2	3.3	3.5	3.5	3.6	3.7	3.7	3.7
4	4.7	5.2	5.6	5.9	6.2	6.5	6.7	7.0	7.2
6	6.1	6.7	7.4	7.9	8.5	9.0	9.5	9.9	10.3
8	7.1	8.0	8.9	9.7	10.4	11.2	11.8	12.5	13.1
10	8.1	9.1	10.2	11.2	12.1	13.1	14.0	14.8	15.7
12	8.8	10.1	11.3	12.5	13.6	14.8	15.8	16.9	17.9
14	9.5	10.9	12.3	13.6	15.0	16.3	17.5	18.8	20.0
16	10.1	11.7	13.2	14.7	16.1	17.6	19.0	20.4	21.8
18	10.6	12.3	13.9	15.6	17.2	18.8	20.4	21.9	23.5
20	11.1	12.9	14.6	16.4	18.1	19.8	21.5	23.2	24.9
22	11.5	13.4	15.2	17.1	18.9	20.8	22.6	24.4	26.3
24	11.8	13.8	15.8	17.7	19.7	21.6	23.6	25.5	27.5
26	12.2	14.2	16.2	18.3	20.3	22.4	24.4	26.5	28.5
28	12.4	14.5	16.7	18.8	20.9	23.0	25.2	27.3	29.5
30	12.7	14.8	17.0	19.2	21.4	23.6	25.9	28.1	30.3
32	12.9	15.1	17.4	19.6	21.9	24.2	26.5	28.8	31.1
34	13.1	15.4	17.7	20.0	22.3	24.6	27.0	29.4	31.8
36	13.3	15.6	17.9	20.3	22.7	25.1	27.5	29.9	32.4
38	13.4	15.8	18.2	20.6	23.0	25.5	27.9	30.4	33.0
40	13.6	15.9	18.4	20.8	23.3	25.8	28.3	30.9	33.4
42	13.7	16.1	18.6	21.0	23.6	26.1	28.7	31.3	33.9
44	13.8	16.2	18.7	21.2	23.8	26.4	29.0	31.6	34.3
46	13.9	16.4	18.9	21.4	24.0	26.6	29.3	31.9	34.6
48	14.0	16.5	19.0	21.6	24.2	26.8	29.5	32.2	35.0
50	14.1	16.6	19.1	21.7	24.4	27.0	29.7	32.5	35.2
52	14.1	16.7	19.2	21.9	24.5	27.2	29.9	32.7	35.5
54	14.2	16.7	19.3	22.0	24.7	27.4	30.1	32.9	35.7
56	14.2	16.8	19.4	22.1	24.8	27.5	30.3	33.1	35.9
58	14.3	16.9	19.5	22.2	24.9	27.6	30.4	33.3	36.1
60	14.3	16.9	19.6	22.3	25.0	27.8	30.6	33.4	36.3

Sugar Maple and Northern Hardwood Stocking Guide



(from Tubbs 1977)

DBHq (cm)	110% Trees # ha	110% BA m^2/ha	A line Trees # ha	A line BA m^2/ha	90% Trees # ha	90% BA m^2/ha	80% Trees # ha	80% BA m^2/ha	70% Trees # ha	70% BA m^2/ha	B line Trees # ha	B line BA m^2/ha	50% Trees # ha	50% BA m^2/ha	C line Trees # ha	C line BA m^2/ha
18	708	17.99	644	16.35	579	14.72	515	13.08	451	11.45	411	10.43	322	8.18	309	7.85
22	515	19.97	468	18.16	421	16.34	375	14.53	328	12.71	299	11.58	234	9.08	225	8.72
26	395	21.73	359	19.75	323	17.78	287	15.80	252	13.83	229	12.60	180	9.88	172	9.48
30	315	23.18	286	21.07	258	18.96	229	16.85	201	14.75	183	13.44	143	10.53	137	10.11
34	258	24.35	235	22.14	211	19.92	188	17.71	164	15.50	150	14.12	117	11.07	113	10.63
38	217	25.30	197	23.00	177	20.70	158	18.40	138	16.10	126	14.67	98	11.50	95	11.04
42	185	26.07	168	23.70	151	21.33	134	18.96	118	16.59	107	15.12	84	11.85	81	11.38
46	160	26.71	145	24.28	131	21.85	116	19.43	102	17.00	93	15.49	73	12.14	70	11.66
50	140	27.24	127	24.76	115	22.29	102	19.81	89	17.33	81	15.80	64	12.38	61	11.89
54	124	27.68	113	25.16	102	22.65	90	20.13	79	17.62	72	16.06	56	12.58	54	12.08
58	111	28.06	101	25.51	91	22.96	81	20.40	71	17.85	64	16.27	50	12.75	48	12.24
62	100	28.38	91	25.80	82	23.22	73	20.64	63	18.06	58	16.46	45	12.90	44	12.38

Sugar Maple Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0143	0.0211	0.0276	0.0340	0.0401	0.0461	0.0518	0.0574	0.0628	0.0681	0.0732	0.0781	0.0829	0.0876
12	0.0206	0.0304	0.0398	0.0489	0.0578	0.0663	0.0746	0.0827	0.0905	0.0980	0.1054	0.1125	0.1194	0.1261
14	0.0280	0.0413	0.0542	0.0666	0.0787	0.0903	0.1016	0.1125	0.1231	0.1334	0.1434	0.1531	0.1625	0.1717
16	0.0366	0.0540	0.0708	0.0870	0.1027	0.1180	0.1327	0.1470	0.1608	0.1743	0.1873	0.2000	0.2123	0.2243
18	0.0463	0.0683	0.0896	0.1101	0.1300	0.1493	0.1679	0.1860	0.2036	0.2206	0.2371	0.2531	0.2687	0.2838
20	0.0572	0.0843	0.1106	0.1360	0.1605	0.1843	0.2073	0.2297	0.2513	0.2723	0.2927	0.3125	0.3317	0.3504
22	0.0692	0.1021	0.1338	0.1645	0.1942	0.2230	0.2509	0.2779	0.3041	0.3295	0.3542	0.3781	0.4014	0.4240
24	0.0824	0.1215	0.1592	0.1958	0.2312	0.2654	0.2986	0.3307	0.3619	0.3921	0.4215	0.4500	0.4777	0.5046
26	0.0967	0.1425	0.1869	0.2298	0.2713	0.3115	0.3504	0.3881	0.4247	0.4602	0.4947	0.5281	0.5606	0.5922
28	0.1121	0.1653	0.2168	0.2665	0.3146	0.3612	0.4064	0.4501	0.4926	0.5337	0.5737	0.6125	0.6502	0.6868
30	0.1287	0.1898	0.2488	0.3059	0.3612	0.4147	0.4665	0.5167	0.5655	0.6127	0.6586	0.7031	0.7464	0.7884
32	0.1464	0.2159	0.2831	0.3481	0.4109	0.4718	0.5308	0.5879	0.6434	0.6971	0.7493	0.8000	0.8492	0.8970
34		0.2438	0.3196	0.3929	0.4639	0.5326	0.5992	0.6637	0.7263	0.7870	0.8459	0.9031	0.9587	1.0127
36			0.3583	0.4405	0.5201	0.5971	0.6718	0.7441	0.8143	0.8823	0.9483	1.0125	1.0748	1.1353
38				0.4908	0.5795	0.6653	0.7485	0.8291	0.9072	0.9831	1.0566	1.1281	1.1975	1.2649
40				0.5439	0.6421	0.7372	0.8294	0.9187	1.0052	1.0893	1.1708	1.2500	1.3269	1.4016
42				0.5996	0.7079	0.8128	0.9144	1.0128	1.1083	1.2009	1.2908	1.3781	1.4629	1.5453
44					0.7769	0.8920	1.0035	1.1116	1.2164	1.3180	1.4167	1.5125	1.6055	1.6959
46					0.8492	0.9750	1.0968	1.2149	1.3294	1.4405	1.5484	1.6531	1.7548	1.8536
48					0.9246	1.0616	1.1943	1.3229	1.4476	1.5685	1.6859	1.7999	1.9107	2.0183
50						1.1519	1.2959	1.4354	1.5707	1.7020	1.8294	1.9531	2.0732	2.1900
52						1.2459	1.4016	1.5525	1.6989	1.8408	1.9786	2.1124	2.2424	2.3687
54						1.3436	1.5115	1.6743	1.8321	1.9852	2.1338	2.2781	2.4182	2.5544
56							1.6255	1.8006	1.9703	2.1349	2.2948	2.4499	2.6007	2.7471
58							1.7437	1.9315	2.1135	2.2902	2.4616	2.6280	2.7897	2.9469
60							1.8660	2.0670	2.2618	2.4508	2.6343	2.8124	2.9854	3.1536
62							1.9925	2.2071	2.4151	2.6169	2.8128	3.0030	3.1878	3.3674
64								2.3518	2.5734	2.7885	2.9972	3.1999	3.3968	3.5881
66								2.5010	2.7368	2.9655	3.1875	3.4030	3.6124	3.8159
68									2.9052	3.1480	3.3836	3.6124	3.8346	4.0506
70										3.3358	3.5855	3.8280	4.0635	4.2924
72										3.5292	3.7934	4.0499	4.2990	4.5412
74										3.7280	4.0070	4.2780	4.5412	4.7970

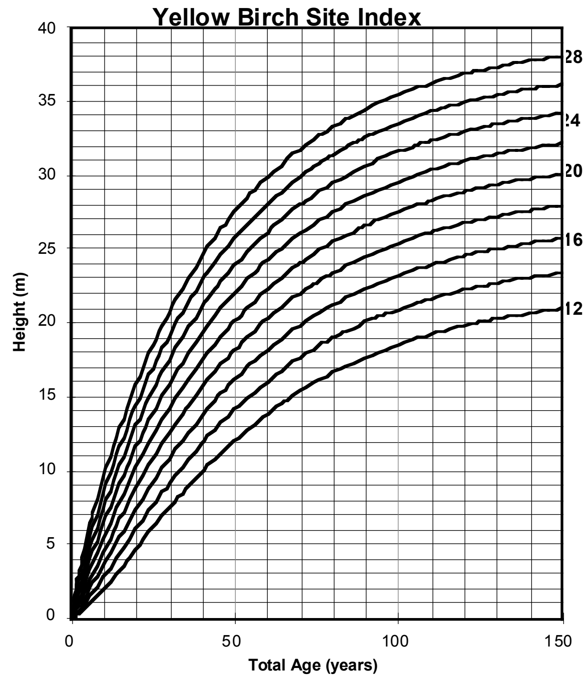
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.145)^2 / (1.046+(0.3048 \cdot 383.972/Height))$ +/- 30.3% Accuracy

——— Denotes range of data 3967 Trees

Yellow Birch Growth & Yield Factsheet

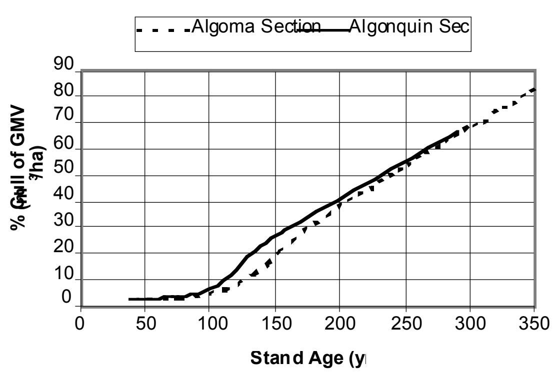
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.74	1.13	1.58	2.11	2.68	3.30	3.97	4.67	5.40
10	1.93	2.68	3.52	4.41	5.35	6.34	7.35	8.39	9.45
15	3.27	4.33	5.46	6.64	7.85	9.08	10.33	11.59	12.86
20	4.65	5.98	7.34	8.73	10.13	11.55	12.97	14.39	15.81
25	6.03	7.56	9.11	10.66	12.22	13.78	15.33	16.87	18.39
30	7.36	9.06	10.75	12.44	14.12	15.78	17.43	19.05	20.67
35	8.63	10.46	12.27	14.06	15.83	17.58	19.30	21.00	22.67
40	9.82	11.76	13.67	15.54	17.39	19.20	20.98	22.73	24.45
45	10.93	12.96	14.95	16.89	18.79	20.65	22.48	24.27	26.03
50	11.96	14.06	16.11	18.11	20.05	21.96	23.82	25.65	27.44
55	12.91	15.07	17.17	19.21	21.19	23.13	25.02	26.87	28.69
60	13.79	16.00	18.13	20.20	22.22	24.18	26.10	27.97	29.81
65	14.59	16.83	19.00	21.10	23.14	25.13	27.06	28.95	30.80
70	15.32	17.60	19.79	21.91	23.97	25.98	27.93	29.83	31.69
75	15.98	18.29	20.50	22.65	24.72	26.74	28.70	30.62	32.49
80	16.58	18.91	21.15	23.30	25.39	27.42	29.39	31.32	33.20
85	17.13	19.48	21.73	23.90	26.00	28.03	30.02	31.95	33.84
90	17.63	19.99	22.25	24.43	26.54	28.58	30.57	32.51	34.40
95	18.08	20.45	22.72	24.91	27.03	29.08	31.07	33.02	34.91
100	18.49	20.87	23.15	25.34	27.47	29.52	31.52	33.47	35.37
105	18.85	21.24	23.53	25.73	27.86	29.92	31.92	33.87	35.78
110	19.18	21.58	23.88	26.08	28.21	30.28	32.28	34.24	36.15
115	19.48	21.89	24.19	26.40	28.53	30.60	32.61	34.56	36.47
120	19.75	22.16	24.46	26.68	28.81	30.89	32.90	34.86	36.77
125	20.00	22.41	24.71	26.93	29.07	31.14	33.16	35.12	37.03
130	20.22	22.63	24.94	27.16	29.30	31.37	33.39	35.35	37.27
135	20.41	22.83	25.14	27.36	29.51	31.58	33.60	35.56	37.48
140	20.59	23.01	25.32	27.55	29.69	31.77	33.79	35.75	37.67
145	20.75	23.17	25.49	27.71	29.86	31.94	33.95	35.92	37.84
150	24.47	27.31	29.99	32.54	34.98	37.33	39.60	41.79	43.92

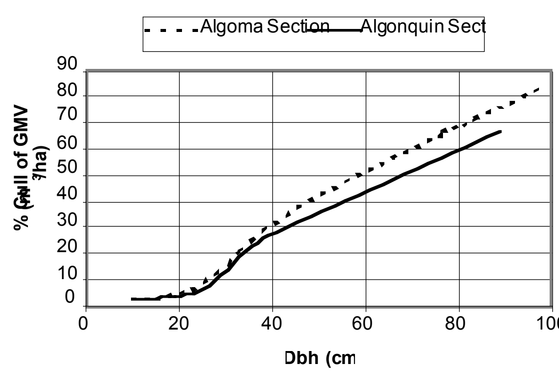


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.0522	0.6768	-0.0217	15.4232	-0.6354	0.99	0.39	1.5
SI	0.1817	1.2430	-0.0110	-3.0184	-0.3180	0.98	0.62	2.3

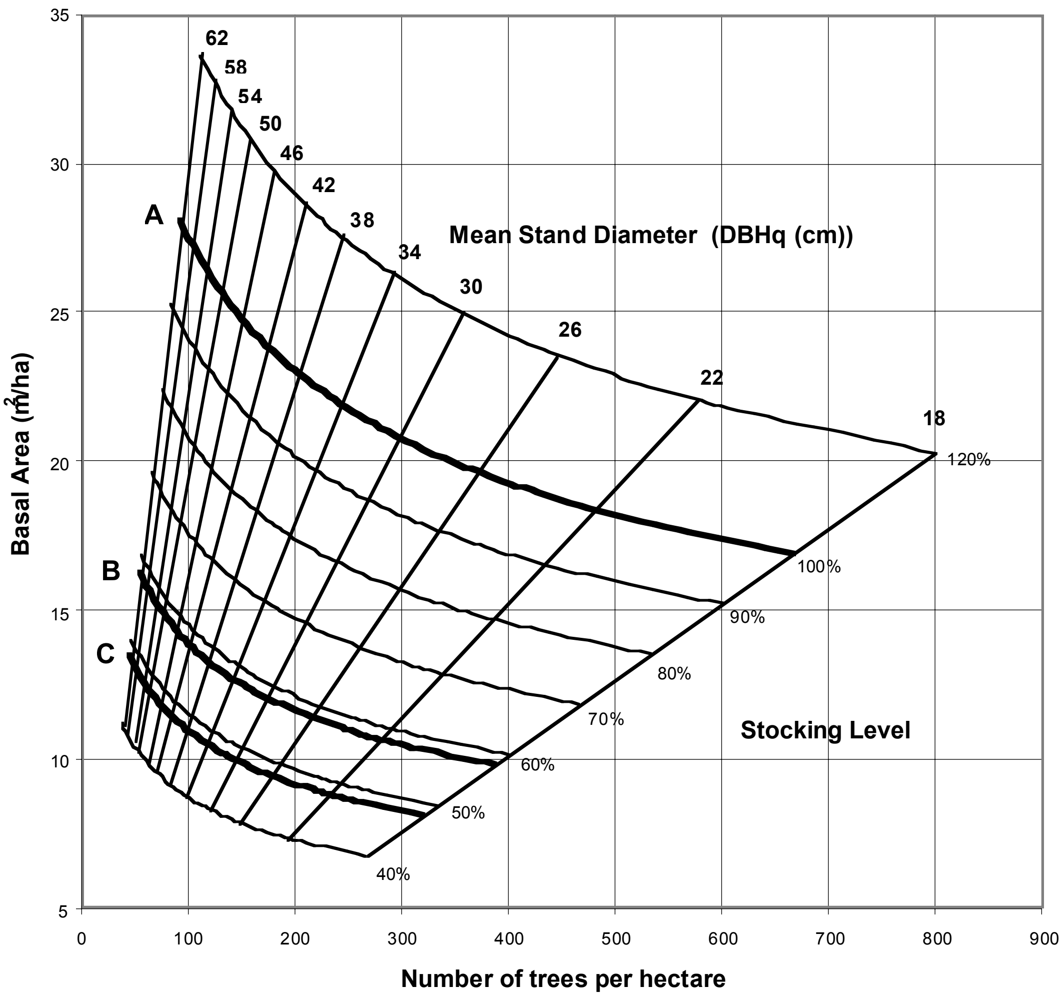
Data Source: *Carmean 1978.* *Northwest Wisconsin and Upper Michigan.* *119 plots having 459 dominant and Codominant trees.* *Stem analysis, nonlinear regression, polymorphic.* ***Add 4 years to dbh age to obtain total age.***





Data Source:Morawski, Z.J.R. 1978 1418 Trees

Yellow Birch Stocking Guide



(from Crow and Erdman)

	120%		A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	800	20.3	666	16.9	600	15.2	533	13.5	466	11.8	387	9.8	333	8.5	320	8.1
22	581	22.0	484	18.3	436	16.5	388	14.7	339	12.8	281	10.6	242	9.2	233	8.8
26	446	23.6	372	19.6	334	17.7	297	15.7	260	13.8	215	11.4	186	9.8	178	9.4
30	355	25.0	296	20.8	266	18.8	237	16.7	207	14.6	172	12.1	148	10.4	142	10.0
34	291	26.3	243	21.9	218	19.7	194	17.5	170	15.4	141	12.7	121	11.0	116	10.5
38	244	27.5	203	23.0	183	20.7	163	18.4	142	16.1	118	13.3	102	11.5	98	11.0
42	208	28.7	173	23.9	156	21.5	139	19.1	121	16.7	101	13.9	87	12.0	83	11.5
46	180	29.8	150	24.8	135	22.3	120	19.9	105	17.4	87	14.4	75	12.4	72	11.9
50	158	30.8	131	25.7	118	23.1	105	20.5	92	18.0	76	14.9	66	12.8	63	12.3
54	140	31.8	116	26.5	105	23.9	93	21.2	81	18.6	67	15.4	58	13.3	56	12.7
58	125	32.8	104	27.3	93	24.6	83	21.8	73	19.1	60	15.8	52	13.6	50	13.1
62	112	33.7	93	28.1	84	25.2	75	22.4	65	19.6	54	16.3	47	14.03	45	13.5

Yellow Birch Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0156	0.0228	0.0296	0.0361	0.0423	0.0482	0.0539	0.0593	0.0644	0.0694	0.0741	0.0787	0.0830	0.0872
12	0.0224	0.0328	0.0427	0.0520	0.0610	0.0695	0.0776	0.0854	0.0928	0.0999	0.1068	0.1133	0.1196	0.1256
14	0.0305	0.0447	0.0581	0.0708	0.0830	0.0946	0.1056	0.1162	0.1263	0.1360	0.1453	0.1542	0.1628	0.1710
16	0.0399	0.0583	0.0758	0.0925	0.1084	0.1235	0.1380	0.1518	0.1650	0.1776	0.1898	0.2014	0.2126	0.2233
18	0.0505	0.0738	0.0960	0.1171	0.1371	0.1563	0.1746	0.1921	0.2088	0.2248	0.2402	0.2549	0.2691	0.2827
20	0.0623	0.0911	0.1185	0.1445	0.1693	0.1930	0.2156	0.2371	0.2578	0.2776	0.2965	0.3147	0.3322	0.3490
22	0.0754	0.1103	0.1434	0.1749	0.2049	0.2335	0.2608	0.2869	0.3119	0.3359	0.3588	0.3808	0.4019	0.4223
24		0.1312	0.1706	0.2081	0.2438	0.2779	0.3104	0.3415	0.3712	0.3997	0.4270	0.4532	0.4784	0.5025
26			0.2002	0.2442	0.2861	0.3261	0.3643	0.4008	0.4357	0.4691	0.5011	0.5319	0.5614	0.5898
28				0.2833	0.3319	0.3782	0.4225	0.4648	0.5053	0.5440	0.5812	0.6169	0.6511	0.6840
30				0.3252	0.3810	0.4342	0.4850	0.5336	0.5800	0.6245	0.6672	0.7081	0.7474	0.7852
32				0.3700	0.4335	0.4940	0.5518	0.6071	0.6600	0.7106	0.7591	0.8057	0.8504	0.8934
34					0.4893	0.5577	0.6230	0.6853	0.7450	0.8022	0.8570	0.9095	0.9600	1.0085
36					0.5486	0.6252	0.6984	0.7683	0.8353	0.8993	0.9608	1.0197	1.0763	1.1307
38						0.6966	0.7782	0.8561	0.9306	1.0020	1.0705	1.1361	1.1992	1.2598
40						0.7719	0.8622	0.9486	1.0312	1.1103	1.1861	1.2589	1.3288	1.3959
42						0.8510	0.9506	1.0458	1.1369	1.2241	1.3077	1.3879	1.4650	1.5390
44						0.9340	1.0433	1.1478	1.2477	1.3435	1.4352	1.5233	1.6078	1.6890
46						1.0208	1.1403	1.2545	1.3637	1.4684	1.5687	1.6649	1.7573	1.8461
48						1.1115	1.2416	1.3659	1.4849	1.5988	1.7080	1.8128	1.9134	2.0101
50						1.2061	1.3472	1.4821	1.6112	1.7348	1.8533	1.9670	2.0762	2.1811
52						1.3045	1.4571	1.6031	1.7427	1.8764	2.0046	2.1275	2.2456	2.3591
54						1.4068	1.5714	1.7288	1.8793	2.0235	2.1617	2.2943	2.4217	2.5440
56						1.5129	1.6899	1.8592	2.0211	2.1762	2.3248	2.4674	2.6044	2.7359
58						1.6229	1.8128	1.9944	2.1680	2.3344	2.4938	2.6468	2.7937	2.9349
60							1.9400	2.1343	2.3201	2.4982	2.6688	2.8325	2.9897	3.1408
62								2.2789	2.4774	2.6675	2.8497	3.0245	3.1923	3.3536
64								2.4283	2.6398	2.8424	3.0365	3.2228	3.4016	3.5735
66									2.8074	3.0228	3.2292	3.4273	3.6175	3.8003
68									2.9801	3.2087	3.4279	3.6382	3.8401	4.0341
70										3.4003	3.6325	3.8554	4.0693	4.2749
72										3.5974	3.8431	4.0788	4.3052	4.5227
74										3.8000	4.0595	4.3086	4.5477	4.7774

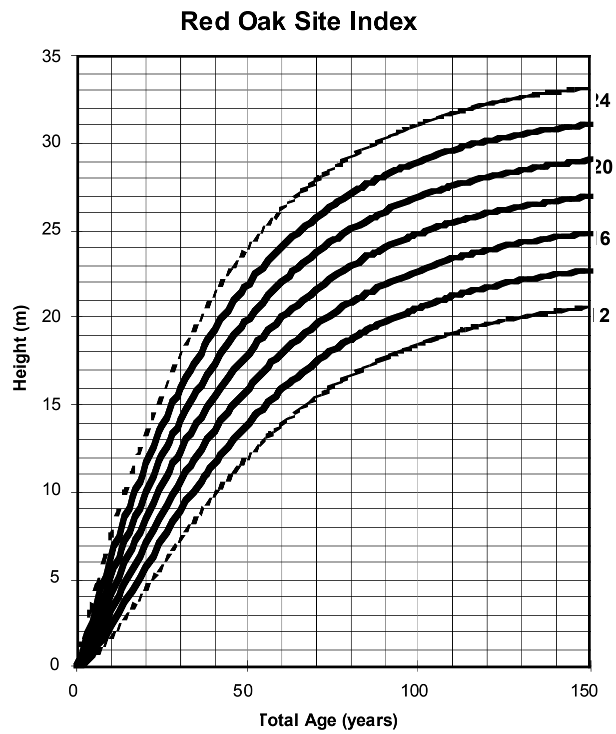
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.181)^2 / (1.449+(0.3048 \cdot 344.754/Height))$ +/- 34.3% Accuracy

——— Denotes range of data 1733 Trees

Red Oak Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24
5	0.61	0.96	1.40	1.92	2.54	3.24	4.01
10	1.72	2.44	3.27	4.19	5.22	6.31	7.49
15	3.04	4.07	5.21	6.43	7.74	9.11	10.55
20	4.45	5.73	7.11	8.55	10.07	11.63	13.24
25	5.86	7.35	8.91	10.52	12.19	13.89	15.62
30	7.24	8.89	10.59	12.32	14.10	15.90	17.73
35	8.55	10.33	12.14	13.97	15.83	17.70	19.59
40	9.79	11.66	13.55	15.45	17.38	19.30	21.24
45	10.94	12.88	14.84	16.79	18.76	20.73	22.70
50	12.00	14.00	16.00	18.00	20.00	22.00	24.00
55	12.97	15.02	17.05	19.08	21.11	23.13	25.14
60	13.86	15.93	18.00	20.04	22.09	24.13	26.16
65	14.66	16.76	18.85	20.91	22.97	25.02	27.06
70	15.39	17.51	19.61	21.68	23.75	25.81	27.85
75	16.05	18.18	20.29	22.37	24.45	26.51	28.56
80	16.64	18.78	20.90	22.99	25.07	27.13	29.19
85	17.17	19.32	21.44	23.53	25.62	27.68	29.74
90	17.64	19.80	21.93	24.02	26.11	28.17	30.23
95	18.07	20.23	22.36	24.45	26.54	28.61	30.67
100	18.45	20.61	22.74	24.84	26.93	28.99	31.05
105	18.79	20.95	23.08	25.18	27.27	29.34	31.39
110	19.10	21.26	23.39	25.49	27.57	29.64	31.70
115	19.37	21.53	23.66	25.76	27.84	29.91	31.96
120	19.61	21.77	23.90	26.00	28.08	30.15	32.20
125	19.82	21.98	24.11	26.21	28.30	30.36	32.41
130	20.02	22.18	24.30	26.40	28.48	30.55	32.60
135	20.19	22.35	24.47	26.57	28.65	30.71	32.77
140	20.34	22.50	24.62	26.72	28.80	30.86	32.91
145	20.47	22.63	24.76	26.85	28.93	30.99	33.04
150	20.59	22.75	24.87	26.97	29.05	31.11	33.16

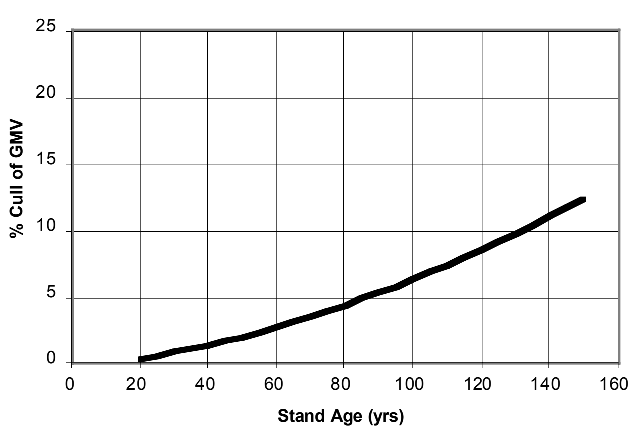


$Ht = [b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	6.1785	0.6619	-0.0241	25.0185	-0.7400	0.99	1.32	4.9
SI	0.1692	1.2648	-0.0110	-3.4334	-0.3557	0.97	2.09	7.8

Data Source: Carmean 1978. Northern Wisconsin and Upper Michigan. 37 plots with 136 dominant and Codominant trees. Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***

Cull as a Percent of Gross Merchantable Volume

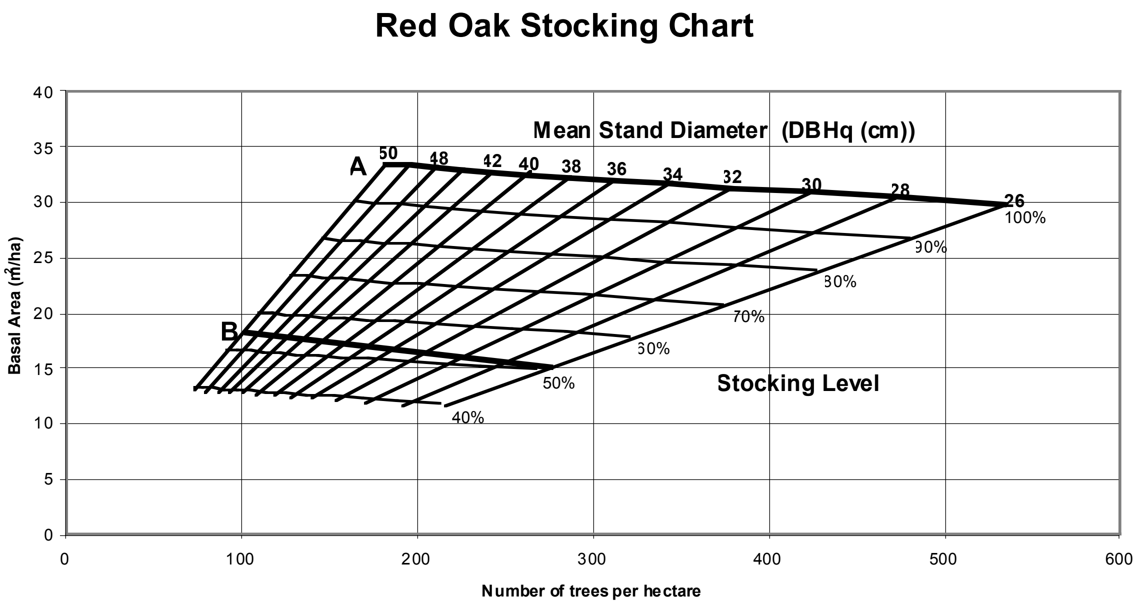


Cull $= 0.0031*Age^{1.6557}$

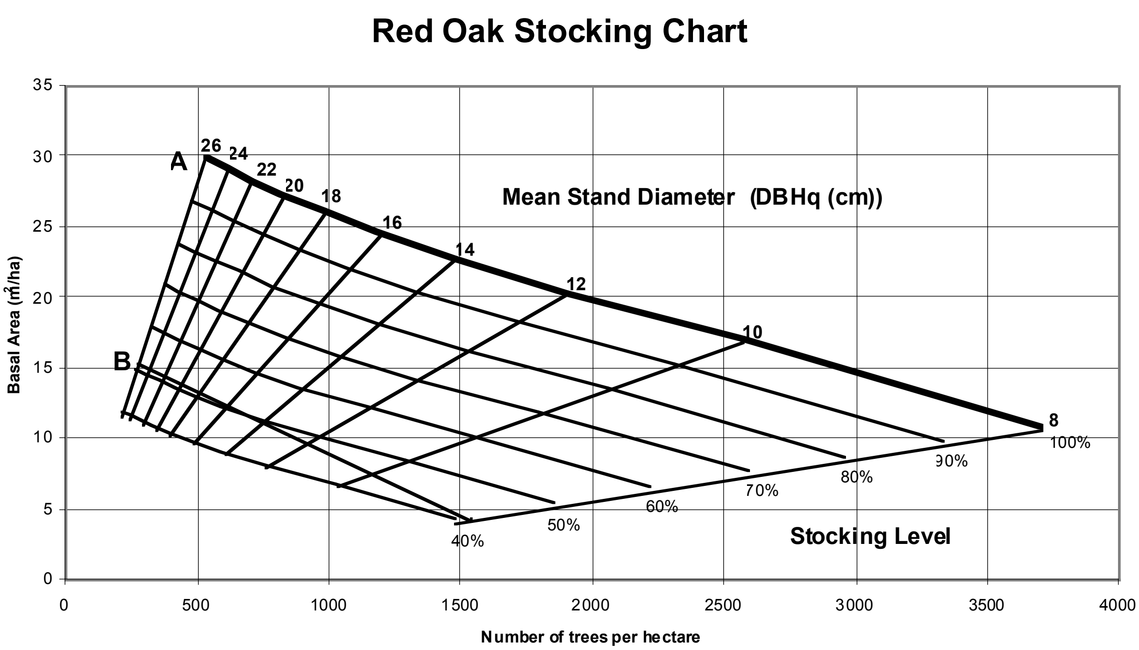
Data Source: Discussion by Basham, J.T. 1991. 42 Trees

Cull as a % of Gross Merchantable Volume					
Age	%	Age	%	Age	%
20	0.44	105	6.88	190	18.38
25	0.64	110	7.44	195	19.19
30	0.87	115	8.00	200	20.01
35	1.12	120	8.59	205	20.84
40	1.39	125	9.19	210	21.69
45	1.69	130	9.80	215	22.55
50	2.02	135	10.44	220	23.43
55	2.36	140	11.08	225	24.31
60	2.73	145	11.75	230	25.22
65	3.11	150	12.43	235	26.13
70	3.52	155	13.12	240	27.06
75	3.94	160	13.83	245	28.00
80	4.39	165	14.55	250	28.95
85	4.85	170	15.29	255	29.91
90	5.33	175	16.04	260	30.89
95	5.83	180	16.80	265	31.88
100	6.35	185	17.58	270	32.88

Large trees



Small trees



(from McGill et al. 1991)

Red Oak Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0160	0.0233	0.0302	0.0368	0.0431	0.0490	0.0547	0.0601	0.0653	0.0702	0.0749	0.0794	0.0837	0.0879
12	0.0230	0.0335	0.0435	0.0530	0.0620	0.0706	0.0788	0.0866	0.0940	0.1011	0.1079	0.1144	0.1206	0.1266
14	0.0313	0.0457	0.0593	0.0722	0.0844	0.0961	0.1072	0.1178	0.1279	0.1376	0.1468	0.1557	0.1641	0.1723
16	0.0409	0.0596	0.0774	0.0943	0.1103	0.1255	0.1400	0.1539	0.1671	0.1797	0.1918	0.2033	0.2144	0.2250
18	0.0517	0.0755	0.0980	0.1193	0.1396	0.1589	0.1772	0.1947	0.2115	0.2274	0.2427	0.2573	0.2713	0.2848
20		0.0932	0.1209	0.1473	0.1723	0.1961	0.2188	0.2404	0.2611	0.2808	0.2996	0.3177	0.3350	0.3516
22		0.1127	0.1463	0.1782	0.2085	0.2373	0.2648	0.2909	0.3159	0.3397	0.3625	0.3844	0.4053	0.4254
24			0.1742	0.2121	0.2481	0.2824	0.3151	0.3462	0.3759	0.4043	0.4314	0.4574	0.4823	0.5062
26			0.2044	0.2489	0.2912	0.3315	0.3698	0.4063	0.4412	0.4745	0.5064	0.5369	0.5661	0.5941
28				0.2887	0.3378	0.3844	0.4289	0.4712	0.5117	0.5503	0.5873	0.6226	0.6565	0.6890
30				0.3314	0.3877	0.4413	0.4923	0.5409	0.5874	0.6317	0.6741	0.7148	0.7537	0.7910
32				0.3771	0.4412	0.5021	0.5601	0.6155	0.6683	0.7188	0.7670	0.8132	0.8575	0.9000
34				0.4257	0.4980	0.5668	0.6323	0.6948	0.7544	0.8114	0.8659	0.9181	0.9680	1.0160
36				0.4772	0.5583	0.6355	0.7089	0.7790	0.8458	0.9097	0.9708	1.0292	1.0853	1.1390
38				0.5317	0.6221	0.7080	0.7899	0.8679	0.9424	1.0136	1.0816	1.1468	1.2092	1.2691
40					0.6893	0.7845	0.8752	0.9617	1.0442	1.1231	1.1985	1.2707	1.3399	1.4062
42					0.7600	0.8650	0.9649	1.0603	1.1512	1.2382	1.3213	1.4009	1.4772	1.5504
44					0.8341	0.9493	1.0590	1.1636	1.2635	1.3589	1.4501	1.5375	1.6212	1.7015
46						1.0375	1.1575	1.2718	1.3810	1.4852	1.5850	1.6805	1.7720	1.8597
48							1.2603	1.3848	1.5037	1.6172	1.7258	1.8298	1.9294	2.0249
50							1.3675	1.5026	1.6316	1.7548	1.8726	1.9854	2.0935	2.1972
52							1.4791	1.6252	1.7647	1.8980	2.0254	2.1474	2.2644	2.3765
54								1.7527	1.9031	2.0468	2.1842	2.3158	2.4419	2.5628
56								1.8849	2.0466	2.2012	2.3490	2.4905	2.6261	2.7562
58									2.1954	2.3612	2.5198	2.6716	2.8170	2.9566
60									2.3495	2.5269	2.6966	2.8590	3.0147	3.1640
62									2.5087	2.6981	2.8793	3.0528	3.2190	3.3784
64									2.6732	2.8750	3.0681	3.2529	3.4300	3.5999
66									2.8429	3.0575	3.2628	3.4594	3.6478	3.8284
68									3.0178	3.2456	3.4636	3.6722	3.8722	4.0640
70										3.4394	3.6703	3.8914	4.1033	4.3065
72											3.8830	4.1170	4.3411	4.5561
74											4.1018	4.3489	4.5857	4.8128

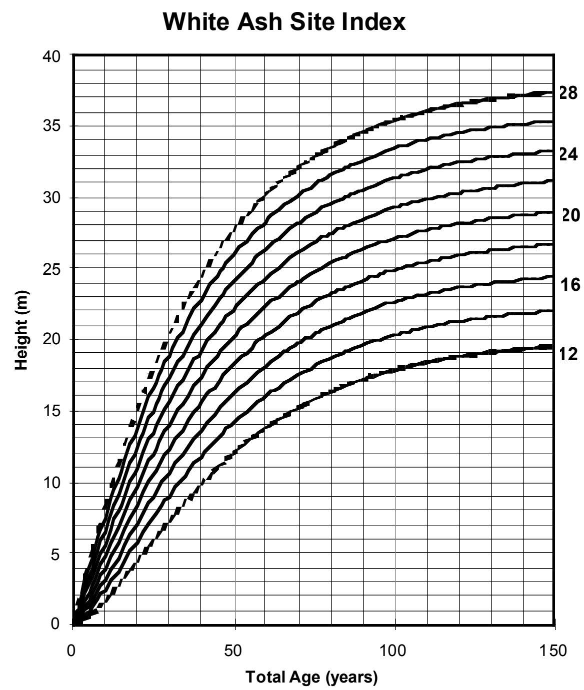
Honer's (1983) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.145)^2 / (1.512+(0.3048 \cdot 336.509/Height))$ +/- 13.8 % Accuracy

——— Denotes range of data 40 Trees

White Ash Growth & Yield Factsheet

Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.57	0.87	1.22	1.63	2.09	2.59	3.13	3.70	4.31
10	1.68	2.33	3.05	3.83	4.66	5.53	6.44	7.37	8.33
15	3.02	3.99	5.02	6.10	7.22	8.36	9.54	10.73	11.94
20	4.45	5.69	6.97	8.29	9.63	10.99	12.36	13.75	15.14
25	5.88	7.34	8.83	10.34	11.85	13.38	14.91	16.43	17.96
30	7.28	8.91	10.57	12.22	13.88	15.53	17.18	18.81	20.45
35	8.59	10.38	12.16	13.94	15.70	17.45	19.19	20.92	22.63
40	9.81	11.72	13.61	15.48	17.33	19.17	20.98	22.77	24.55
45	10.94	12.94	14.92	16.87	18.79	20.69	22.56	24.41	26.23
50	11.96	14.05	16.09	18.10	20.08	22.03	23.95	25.84	27.71
55	12.89	15.04	17.14	19.20	21.23	23.22	25.17	27.10	29.00
60	13.72	15.92	18.07	20.18	22.24	24.26	26.25	28.21	30.13
65	14.47	16.72	18.90	21.04	23.13	25.18	27.20	29.18	31.13
70	15.14	17.42	19.64	21.80	23.92	25.99	28.03	30.03	31.99
75	15.73	18.04	20.29	22.47	24.61	26.70	28.76	30.77	32.75
80	16.25	18.59	20.86	23.07	25.22	27.33	29.40	31.43	33.42
85	16.72	19.08	21.36	23.59	25.76	27.88	29.96	32.00	34.00
90	17.13	19.51	21.81	24.04	26.23	28.36	30.45	32.50	34.51
95	17.49	19.88	22.20	24.45	26.64	28.78	30.88	32.93	34.96
100	17.81	20.22	22.54	24.80	27.00	29.15	31.25	33.32	35.34
105	18.10	20.51	22.84	25.11	27.32	29.47	31.58	33.65	35.69
110	18.34	20.77	23.11	25.38	27.59	29.76	31.87	33.95	35.98
115	18.56	20.99	23.34	25.62	27.84	30.00	32.12	34.20	36.24
120	18.75	21.19	23.54	25.83	28.05	30.22	32.35	34.43	36.47
125	18.92	21.36	23.72	26.01	28.24	30.41	32.54	34.62	36.67
130	19.07	21.51	23.88	26.17	28.40	30.58	32.71	34.80	36.85
135	19.20	21.65	24.01	26.31	28.54	30.72	32.86	34.95	37.00
140	19.31	21.76	24.13	26.43	28.67	30.85	32.98	35.08	37.13
145	19.41	21.87	24.24	26.54	28.78	30.96	33.10	35.19	37.25
150	19.50	21.95	24.33	26.63	28.87	31.06	33.20	35.29	37.35

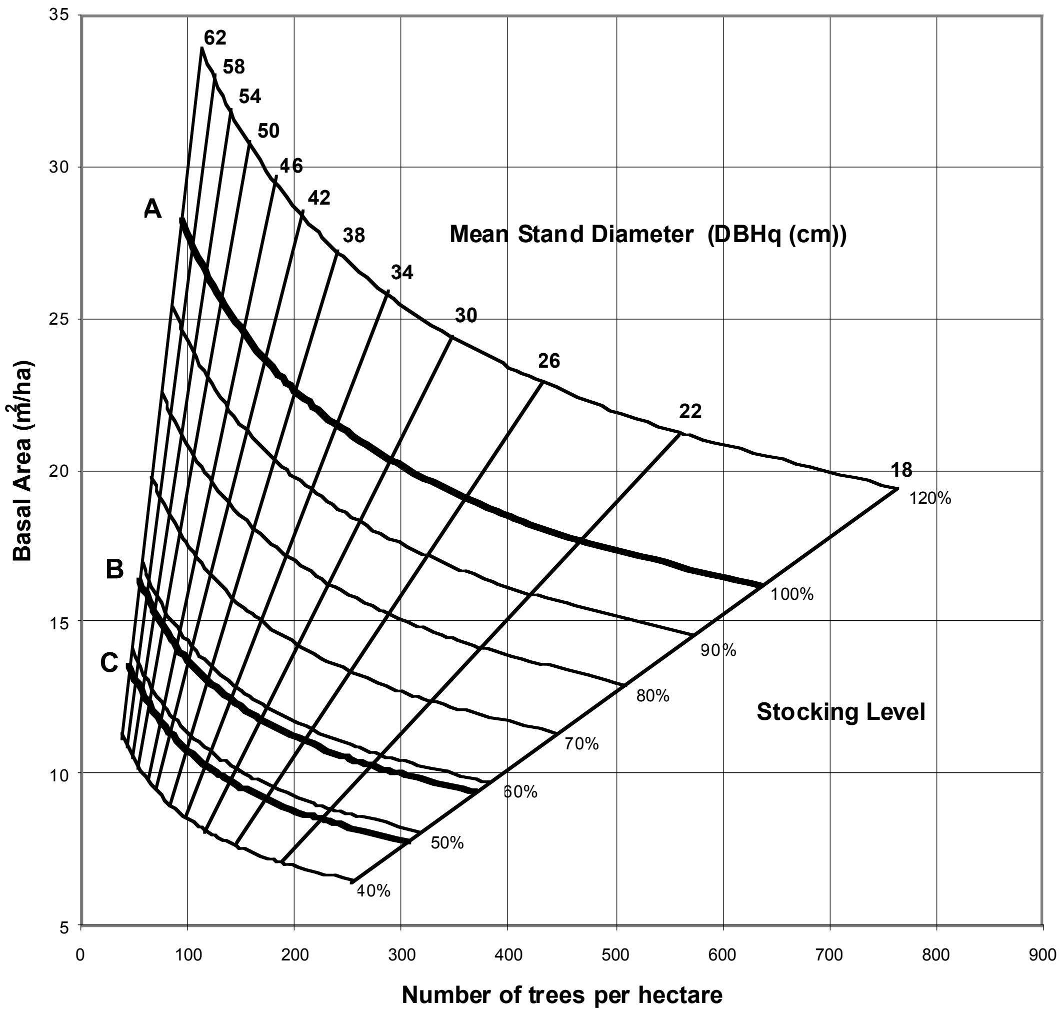


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*3048^{b5})}]*3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	4.1492	0.7531	-0.0269	14.5384	-0.5811	0.99	0.42	1.6
SI	0.1728	1.2560	-0.0110	-3.3605	-0.3452	0.99	0.61	2.9

Data Source: Carmean 1978. Northern Wisconsin and Upper Michigan. 73 plots having 275 dominant and Codominant trees.
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***

White Ash Stocking Guide

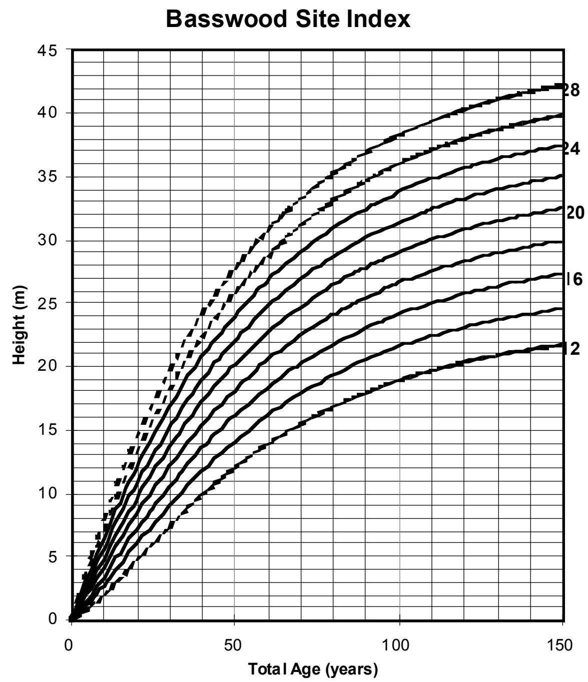


(from Crow and Erdman)

	120%		A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	763	19.4	636	16.2	572	14.6	509	12.9	445	11.3	381	9.7	318	8.1	305	7.8
22	559	21.2	466	17.7	419	15.9	373	14.2	326	12.4	279	10.6	233	8.9	224	8.5
26	431	22.9	360	19.1	324	17.2	288	15.3	252	13.4	216	11.5	180	9.5	173	9.2
30	346	24.4	288	20.4	259	18.3	230	16.3	202	14.3	173	12.2	144	10.2	138	9.8
34	285	25.8	237	21.5	213	19.4	190	17.2	166	15.1	142	12.9	119	10.8	114	10.3
38	240	27.2	200	22.6	180	20.4	160	18.1	140	15.9	120	13.6	100	11.3	96	10.9
42	205	28.4	171	23.7	154	21.3	137	18.9	120	16.6	103	14.2	85	11.8	82	11.4
46	178	29.6	148	24.7	134	22.2	119	19.7	104	17.3	89	14.8	74	12.3	71	11.8
50	157	30.7	130	25.6	117	23.1	104	20.5	91	17.9	78	15.4	65	12.8	63	12.3
54	139	31.8	116	26.5	104	23.9	93	21.2	81	18.6	69	15.9	58	13.3	56	12.7
58	124	32.9	104	27.4	93	24.6	83	21.9	73	19.2	62	16.4	52	13.7	50	13.1
62	112	33.9	93	28.2	84	25.4	75	22.6	65	19.8	56	16.9	47	14.1	45	13.5

Basswood Growth & Yield Factsheet

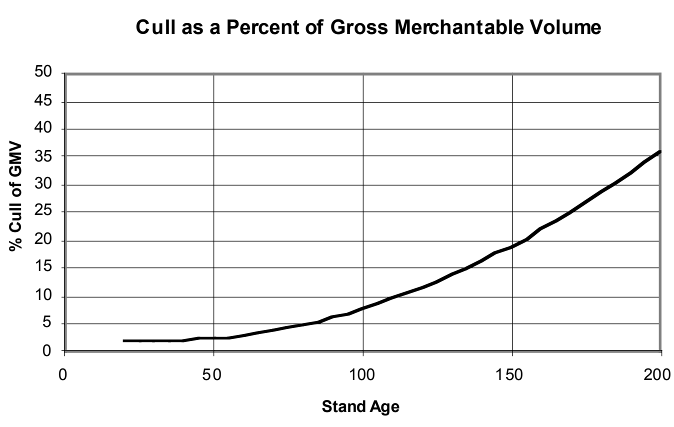
Age	Site Index 12	14	16	18	20	22	24	26	28
5	0.81	1.12	1.47	1.85	2.27	2.71	3.17	3.66	4.17
10	2.01	2.64	3.30	4.01	4.74	5.51	6.30	7.11	7.93
15	3.35	4.25	5.18	6.16	7.15	8.17	9.21	10.27	11.34
20	4.71	5.85	7.02	8.22	9.44	10.67	11.91	13.16	14.42
25	6.06	7.41	8.78	10.17	11.57	12.97	14.39	15.80	17.22
30	7.37	8.90	10.45	12.00	13.55	15.10	16.66	18.21	19.76
35	8.62	10.31	12.00	13.69	15.38	17.06	18.73	20.40	22.06
40	9.81	11.63	13.45	15.27	17.06	18.85	20.63	22.39	24.14
45	10.92	12.87	14.80	16.71	18.61	20.49	22.36	24.20	26.03
50	11.96	14.01	16.04	18.05	20.03	21.99	23.93	25.85	27.75
55	12.92	15.07	17.19	19.27	21.33	23.36	25.37	27.35	29.31
60	13.82	16.05	18.24	20.39	22.52	24.61	26.67	28.71	30.72
65	14.65	16.95	19.21	21.42	23.60	25.75	27.86	29.95	32.01
70	15.41	17.77	20.09	22.36	24.59	26.78	28.94	31.07	33.17
75	16.11	18.53	20.90	23.22	25.49	27.73	29.93	32.09	34.23
80	16.76	19.23	21.64	24.00	26.32	28.59	30.82	33.02	35.18
85	17.35	19.87	22.32	24.72	27.06	29.37	31.63	33.86	36.05
90	17.89	20.45	22.94	25.37	27.75	30.08	32.37	34.62	36.84
95	18.39	20.98	23.50	25.96	28.37	30.73	33.04	35.32	37.56
100	18.84	21.47	24.02	26.50	28.93	31.32	33.65	35.95	38.21
105	19.26	21.91	24.48	26.99	29.45	31.85	34.21	36.52	38.80
110	19.63	22.31	24.91	27.44	29.92	32.34	34.71	37.04	39.33
115	19.98	22.68	25.30	27.85	30.34	32.78	35.17	37.51	39.82
120	20.30	23.02	25.65	28.22	30.73	33.18	35.58	37.94	40.26
125	20.58	23.32	25.98	28.56	31.08	33.54	35.96	38.33	40.66
130	20.84	23.60	26.27	28.86	31.40	33.87	36.30	38.68	41.02
135	21.08	23.85	26.54	29.14	31.69	34.18	36.61	39.00	41.35
140	21.30	24.08	26.78	29.40	31.95	34.45	36.89	39.29	41.65
145	21.50	24.29	27.00	29.63	32.19	34.70	37.15	39.56	41.92
150	21.68	24.48	27.20	29.84	32.41	34.92	37.38	39.80	42.17



$$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	4.7633	0.7576	-0.0194	6.5110	-0.4156	0.99	0.21	0.8
SI	0.1921	1.2010	-0.0100	-2.3009	-0.2331	0.99	0.38	1.4

Data Source: *Carmean 1978.* *Northwest Wisconsin and Upper Michigan.* *122 plots having 483 dominant and Codominant trees.*
Stem analysis, nonlinear regression, polymorphic. ***Add 4 years to dbh age to obtain total age.***



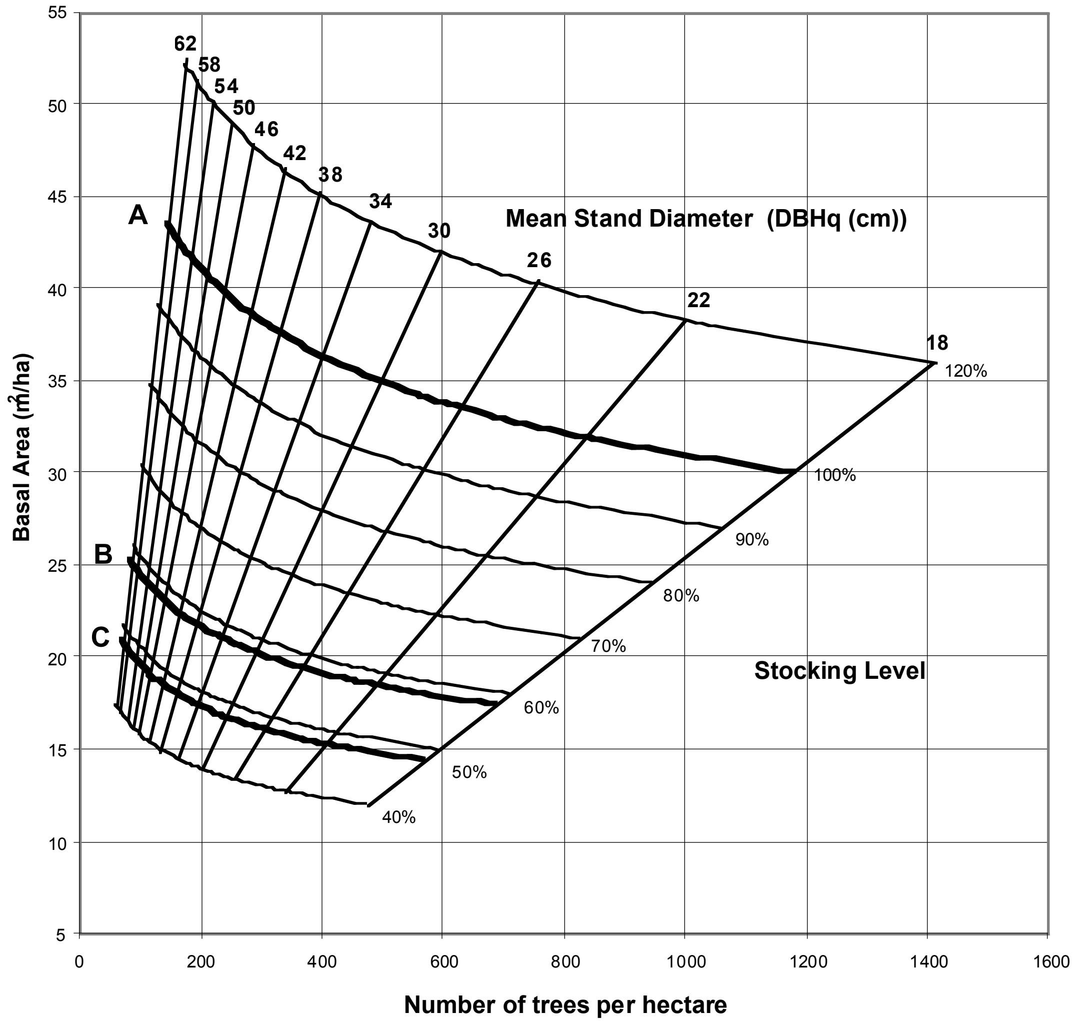
Cull = 0.0012 x Stand Age^2 - 0.0749 x Stand Age + 2.9935

Data Source: Basham, J.T. 1991. 140 Trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%	Age	%
20	1.70	105	8.36	190	32.08
25	1.80	110	9.27	195	34.02
30	1.83	115	10.25	200	36.01
35	1.84	120	11.29		
40	1.92	125	12.38		
45	2.05	130	13.54		
50	2.25	135	14.75		
55	2.50	140	16.03		
60	2.82	145	17.36		
65	3.20	150	18.76		
70	3.63	155	20.21		
75	4.13	160	21.73		
80	4.68	165	23.31		
85	5.30	170	24.94		
90	5.97	175	26.64		
95	6.71	180	28.39		
100	7.50	185	30.21		

Basswood Stocking Guide



(from Crow and Erdman)

DBHq (cm)	120% Trees # ha	120% BA m2/ha	A Line Trees # ha	A Line BA m2/ha	90% Trees # ha	90% BA m2/ha	80% Trees # ha	80% BA m2/ha	70% Trees # ha	70% BA m2/ha	B Line Trees # ha	B Line BA m2/ha	50% Trees # ha	50% BA m2/ha	C Line Trees # ha	C Line BA m2/ha
18	1416	36.02	1180	30.02	1062	27.02	944	24.02	826	21.01	684	17.41	590	15.01	566	14.41
22	1006	38.26	839	31.88	755	28.69	671	25.51	587	22.32	486	18.49	419	15.94	403	15.30
26	758	40.23	631	33.52	568	30.17	505	26.82	442	23.47	366	19.44	316	16.76	303	16.09
30	594	41.99	495	34.99	446	31.49	396	27.99	347	24.49	287	20.30	248	17.50	238	16.80
34	480	43.60	400	36.33	360	32.70	320	29.07	280	25.43	232	21.07	200	18.17	192	17.44
38	397	45.08	331	37.56	298	33.81	265	30.05	232	26.30	192	21.79	166	18.78	159	18.03
42	335	46.45	279	38.71	251	34.84	224	30.97	196	27.10	162	22.45	140	19.35	134	18.58
46	287	47.74	239	39.78	215	35.80	191	31.82	168	27.85	139	23.07	120	19.89	115	19.09
50	249	48.95	208	40.79	187	36.71	166	32.63	145	28.55	120	23.66	104	20.39	100	19.58
54	219	50.09	182	41.74	164	37.57	146	33.39	128	29.22	106	24.21	91	20.87	87	20.04
58	194	51.17	161	42.65	145	38.38	129	34.12	113	29.85	94	24.73	81	21.32	77	20.47
62	173	52.21	144	43.51	130	39.16	115	34.81	101	30.46	84	25.23	72	21.75	69	20.88

Basswood Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0137	0.0203	0.0267	0.0329	0.0389	0.0447	0.0504	0.0559	0.0613	0.0666	0.0717	0.0766	0.0815	0.0862
12	0.0198	0.0292	0.0384	0.0473	0.0560	0.0644	0.0726	0.0806	0.0883	0.0959	0.1032	0.1104	0.1173	0.1241
14	0.0269	0.0398	0.0523	0.0644	0.0762	0.0877	0.0988	0.1097	0.1202	0.1305	0.1405	0.1502	0.1597	0.1690
16	0.0352	0.0520	0.0683	0.0841	0.0995	0.1145	0.1291	0.1432	0.1570	0.1704	0.1835	0.1962	0.2086	0.2207
18	0.0445	0.0658	0.0864	0.1065	0.1260	0.1449	0.1634	0.1813	0.1987	0.2157	0.2322	0.2483	0.2640	0.2793
20	0.0550	0.0812	0.1067	0.1315	0.1555	0.1789	0.2017	0.2238	0.2453	0.2663	0.2867	0.3066	0.3260	0.3448
22	0.0665	0.0983	0.1291	0.1591	0.1882	0.2165	0.2440	0.2708	0.2968	0.3222	0.3469	0.3710	0.3944	0.4173
24	0.0791	0.1170	0.1537	0.1893	0.2240	0.2577	0.2904	0.3223	0.3533	0.3834	0.4128	0.4415	0.4694	0.4966
26	0.0929	0.1373	0.1804	0.2222	0.2629	0.3024	0.3408	0.3782	0.4146	0.4500	0.4845	0.5181	0.5509	0.5828
28		0.1592	0.2092	0.2577	0.3049	0.3507	0.3953	0.4386	0.4808	0.5219	0.5619	0.6009	0.6389	0.6759
30		0.1828	0.2401	0.2958	0.3500	0.4026	0.4538	0.5035	0.5520	0.5991	0.6451	0.6898	0.7334	0.7759
32				0.3366	0.3982	0.4581	0.5163	0.5729	0.6280	0.6817	0.7339	0.7848	0.8345	0.8828
34				0.3800	0.4495	0.5171	0.5828	0.6468	0.7090	0.7696	0.8285	0.8860	0.9420	0.9966
36				0.4260	0.5039	0.5797	0.6534	0.7251	0.7948	0.8628	0.9289	0.9933	1.0561	1.1173
38					0.5615	0.6459	0.7280	0.8079	0.8856	0.9613	1.0350	1.1067	1.1767	1.2449
40					0.6222	0.7157	0.8067	0.8952	0.9813	1.0651	1.1468	1.2263	1.3038	1.3794
42						0.7891	0.8894	0.9869	1.0819	1.1743	1.2643	1.3520	1.4375	1.5208
44							0.9761	1.0832	1.1874	1.2888	1.3876	1.4838	1.5776	1.6691
46							1.0668	1.1839	1.2977	1.4086	1.5166	1.6218	1.7243	1.8243
48							1.1616	1.2890	1.4131	1.5338	1.6514	1.7659	1.8775	1.9863
50							1.2604	1.3987	1.5333	1.6643	1.7918	1.9161	2.0372	2.1553
52							1.3633	1.5128	1.6584	1.8001	1.9380	2.0725	2.2035	2.3312
54								1.6314	1.7884	1.9412	2.0900	2.2350	2.3762	2.5140
56								1.7545	1.9233	2.0876	2.2477	2.4036	2.5555	2.7036
58									2.0632	2.2394	2.4111	2.5783	2.7413	2.9002
60									2.2079	2.3965	2.5802	2.7592	2.9336	3.1036
62									2.3575	2.5590	2.7551	2.9462	3.1325	3.3140
64										2.7267	2.9357	3.1394	3.3378	3.5313
66										2.8998	3.1221	3.3386	3.5497	3.7554
68										3.0782	3.3142	3.5440	3.7681	3.9865
70										3.2619	3.5120	3.7556	3.9930	4.2244
72										3.4510	3.7155	3.9733	4.2244	4.4692
74										3.6454	3.9248	4.1971	4.4624	4.7210

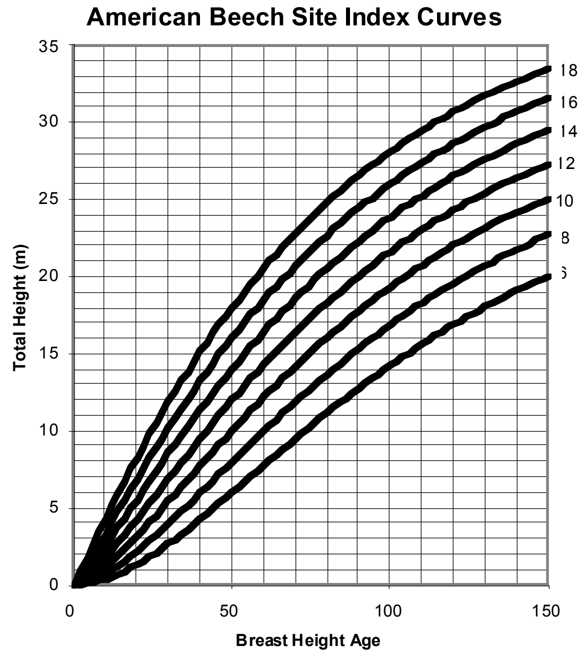
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.145)^2 / (0.948+(0.3048 \cdot 401.456/Height))$ +/- 25.5% Accuracy

Denotes range of data 140 Trees

American Beech Growth & Yield Factsheet

Age	Site Index 6	8	10	12	14	16	18
5	0.1	0.2	0.4	0.7	1.1	1.6	2.1
10	0.4	0.7	1.2	1.8	2.5	3.3	4.3
15	0.8	1.4	2.1	3.0	4.0	5.1	6.3
20	1.3	2.2	3.2	4.3	5.5	6.9	8.3
25	2.0	3.1	4.3	5.6	7.0	8.6	10.1
30	2.7	4.0	5.4	6.9	8.5	10.2	11.9
35	3.5	5.0	6.6	8.2	10.0	11.7	13.6
40	4.3	6.0	7.7	9.5	11.4	13.2	15.1
45	5.1	7.0	8.9	10.8	12.7	14.7	16.6
50	6.0	8.0	10.0	12.0	14.0	16.0	18.0
55	6.9	9.0	11.1	13.2	15.2	17.3	19.3
60	7.8	10.0	12.2	14.3	16.4	18.5	20.6
65	8.6	11.0	13.2	15.4	17.5	19.6	21.7
70	9.5	11.9	14.2	16.4	18.6	20.7	22.8
75	10.3	12.8	15.1	17.4	19.6	21.7	23.8
80	11.2	13.7	16.1	18.3	20.5	22.7	24.8
85	12.0	14.5	16.9	19.2	21.4	23.6	25.7
90	12.8	15.4	17.8	20.1	22.3	24.5	26.6
95	13.5	16.2	18.6	20.9	23.1	25.3	27.4
100	14.3	16.9	19.3	21.7	23.9	26.0	28.1
105	15.0	17.6	20.1	22.4	24.6	26.7	28.8
110	15.6	18.3	20.8	23.1	25.3	27.4	29.5
115	16.3	19.0	21.4	23.7	25.9	28.1	30.1
120	16.9	19.6	22.0	24.3	26.5	28.7	30.7
125	17.5	20.2	22.6	24.9	27.1	29.2	31.3
130	18.1	20.8	23.2	25.5	27.6	29.7	31.8
135	18.6	21.3	23.7	26.0	28.2	30.2	32.3
140	19.1	21.8	24.2	26.5	28.6	30.7	32.7
145	19.6	22.3	24.7	26.9	29.1	31.2	33.2
150	20.1	22.7	25.1	27.4	29.5	31.6	33.6



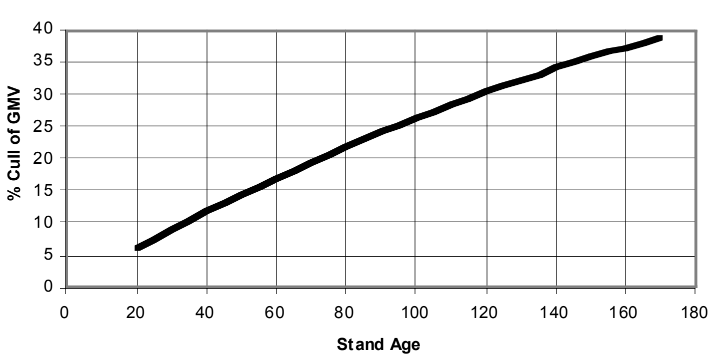
$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{b5})}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	29.7300	0.3631	-0.0127	16.7616	-0.6804	0.99	0.49	0.4
SI	0.2376	1.1312	-0.0109	-1.8550	-0.1430	0.99	0.61	2.9

Data Source: Carmean 1978

Lake States Data. Number of trees used for equation derivation unknown.
Add 4 years to breast-height age to get total age.

Cull as a % of Gross Merchantable Volume



Cull = -0.0005*Stand Age^2 + 0.03136*Stand Age

Data Source: Basham, J.T. 1991. 393 trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%
5	1.56	90	24.17
10	3.09	95	25.28
15	4.59	100	26.36
20	6.07	105	27.42
25	7.53	110	28.45
30	8.96	115	29.45
35	10.36	120	30.43
40	11.74	125	31.39
45	13.10	130	32.32
50	14.43	135	33.22
55	15.74	140	34.10
60	17.02	145	34.96
65	18.27	150	35.79
70	19.50	155	36.60
75	20.71	160	37.38
80	21.89	165	38.13
85	23.04	170	38.86

American Beech Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0164	0.0241	0.0316	0.0388	0.0458	0.0525	0.0591	0.0654	0.0715	0.0774	0.0832	0.0887	0.0941	0.0994
12	0.0236	0.0347	0.0455	0.0559	0.0659	0.0757	0.0851	0.0941	0.1029	0.1115	0.1197	0.1278	0.1356	0.1431
14	0.0321	0.0473	0.0619	0.0761	0.0898	0.1030	0.1158	0.1281	0.1401	0.1517	0.1630	0.1739	0.1845	0.1948
16	0.0419	0.0617	0.0809	0.0994	0.1172	0.1345	0.1512	0.1674	0.1830	0.1982	0.2129	0.2271	0.2410	0.2544
18	0.0530	0.0781	0.1024	0.1258	0.1484	0.1702	0.1914	0.2118	0.2316	0.2508	0.2694	0.2875	0.3050	0.3220
20		0.0965	0.1264	0.1553	0.1832	0.2102	0.2363	0.2615	0.2860	0.3097	0.3326	0.3549	0.3765	0.3975
22		0.1167	0.1529	0.1879	0.2216	0.2543	0.2859	0.3164	0.3460	0.3747	0.4025	0.4294	0.4556	0.4810
24			0.1820	0.2236	0.2638	0.3026	0.3402	0.3766	0.4118	0.4459	0.4790	0.5111	0.5422	0.5724
26			0.2136	0.2624	0.3096	0.3552	0.3993	0.4420	0.4833	0.5233	0.5622	0.5998	0.6363	0.6718
28				0.3043	0.3590	0.4119	0.4631	0.5126	0.5605	0.6069	0.6520	0.6956	0.7380	0.7791
30				0.3493	0.4121	0.4728	0.5316	0.5884	0.6434	0.6968	0.7484	0.7986	0.8472	0.8944
32				0.3975	0.4689	0.5380	0.6048	0.6695	0.7321	0.7927	0.8516	0.9086	0.9639	1.0176
34				0.4487	0.5294	0.6073	0.6828	0.7558	0.8265	0.8949	0.9613	1.0257	1.0882	1.1488
36				0.5031	0.5935	0.6809	0.7655	0.8473	0.9265	1.0033	1.0777	1.1499	1.2200	1.2879
38				0.5605	0.6613	0.7587	0.8529	0.9440	1.0323	1.1179	1.2008	1.2812	1.3593	1.4350
40					0.7327	0.8406	0.9450	1.0460	1.1439	1.2387	1.3306	1.4197	1.5061	1.5900
42					0.8078	0.9268	1.0419	1.1533	1.2611	1.3656	1.4669	1.5652	1.6605	1.7530
44					0.8866	1.0171	1.1435	1.2657	1.3841	1.4988	1.6100	1.7178	1.8224	1.9239
46						1.1117	1.2498	1.3834	1.5128	1.6381	1.7597	1.8775	1.9918	2.1028
48							1.3608	1.5063	1.6472	1.7837	1.9160	2.0443	2.1688	2.2897
50							1.4766	1.6344	1.7873	1.9354	2.0790	2.2182	2.3533	2.4844
52							1.5971	1.7678	1.9332	2.0933	2.2486	2.3992	2.5453	2.6872
54								1.9064	2.0847	2.2575	2.4249	2.5873	2.7449	2.8978
56								2.0502	2.2420	2.4278	2.6079	2.7825	2.9520	3.1165
58									2.4050	2.6043	2.7975	2.9848	3.1666	3.3431
60									2.5737	2.7870	2.9937	3.1942	3.3888	3.5776
62									2.7482	2.9759	3.1967	3.4107	3.6184	3.8201
64									2.9283	3.1710	3.4062	3.6343	3.8557	4.0705
66									3.1142	3.3723	3.6224	3.8650	4.1004	4.3289
68									3.3058	3.5798	3.8453	4.1028	4.3527	4.5952
70										3.7934	4.0748	4.3477	4.6125	4.8695
72											4.3110	4.5997	4.8798	5.1517
74											4.5538	4.8588	5.1547	5.4419

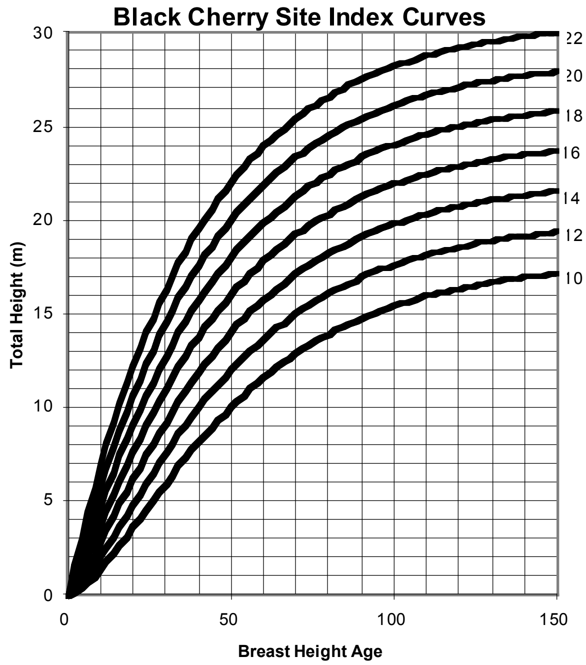
Honer's (1983) Total cubic metre volume equation

Volume (m^3) = $0.0043891 \cdot dbh^2 \cdot (1-0.04365 \cdot 0.145)^2 / (0.959+(0.3048 \cdot 334.829/Height))$ — +/- 25.1 % Accuracy

——— Denotes range of data — 388 Trees

Black Cherry Growth & Yield Factsheet

	Site Index						
Age	**10**	**12**	**14**	**16**	**18**	**20**	**22**
5	0.5	0.8	1.2	1.7	2.3	2.9	3.7
10	1.3	2.0	2.8	3.7	4.7	5.8	6.9
15	2.4	3.4	4.5	5.7	7.0	8.3	9.7
20	3.6	4.8	6.2	7.6	9.1	10.6	12.2
25	4.8	6.2	7.8	9.4	11.0	12.7	14.4
30	6.0	7.6	9.3	11.0	12.7	14.5	16.3
35	7.1	8.8	10.6	12.4	14.3	16.1	18.0
40	8.1	10.0	11.9	13.8	15.7	17.6	19.5
45	9.1	11.0	13.0	14.9	16.9	18.9	20.8
50	10.0	12.0	14.0	16.0	18.0	20.0	22.0
55	10.8	12.9	14.9	16.9	19.0	21.0	23.0
60	11.6	13.7	15.7	17.8	19.8	21.9	23.9
65	12.3	14.4	16.5	18.5	20.6	22.7	24.7
70	12.9	15.0	17.1	19.2	21.3	23.4	25.4
75	13.4	15.6	17.7	19.8	21.9	24.0	26.0
80	13.9	16.1	18.2	20.3	22.4	24.5	26.6
85	14.4	16.5	18.7	20.8	22.9	25.0	27.1
90	14.8	16.9	19.1	21.2	23.3	25.4	27.5
95	15.1	17.3	19.5	21.6	23.7	25.8	27.9
100	15.4	17.6	19.8	21.9	24.0	26.1	28.2
105	15.7	17.9	20.1	22.2	24.3	26.4	28.5
110	15.9	18.2	20.3	22.5	24.6	26.7	28.8
115	16.2	18.4	20.6	22.7	24.8	26.9	29.0
120	16.4	18.6	20.7	22.9	25.0	27.1	29.2
125	16.5	18.7	20.9	23.1	25.2	27.3	29.4
130	16.7	18.9	21.1	23.2	25.3	27.4	29.5
135	16.8	19.0	21.2	23.4	25.5	27.6	29.7
140	16.9	19.2	21.3	23.5	25.6	27.7	29.8
145	17.1	19.3	21.4	23.6	25.7	27.8	29.9
150	17.1	19.4	21.5	23.7	25.8	27.9	30.0



$$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	5.0844	0.6974	-0.0250	20.7996	-0.7114	0.99	0.49	1.7
SI	0.1738	1.2707	-0.0110	-3.5467	-0.3823	0.98	0.68	2.2

Data Source: Carmean 1978

Lake States Data. Number of trees used for equation derivation unknown.

Add 4 Years to breast-height age to get total age.

Black Cherry Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0144	0.0217	0.0289	0.0360	0.0432	0.0504	0.0576	0.0647	0.0719	0.0790	0.0862	0.0933	0.1004	0.1076
12	0.0208	0.0312	0.0416	0.0519	0.0623	0.0726	0.0829	0.0932	0.1035	0.1138	0.1241	0.1344	0.1446	0.1549
14	0.0283	0.0424	0.0566	0.0707	0.0847	0.0988	0.1129	0.1269	0.1409	0.1549	0.1689	0.1829	0.1969	0.2108
16	0.0370	0.0554	0.0739	0.0923	0.1107	0.1291	0.1474	0.1657	0.1841	0.2024	0.2206	0.2389	0.2571	0.2753
18	0.0468	0.0702	0.0935	0.1168	0.1401	0.1633	0.1866	0.2098	0.2330	0.2561	0.2792	0.3023	0.3254	0.3485
20		0.0866	0.1154	0.1442	0.1729	0.2017	0.2303	0.2590	0.2876	0.3162	0.3447	0.3733	0.4018	0.4302
22		0.1048	0.1397	0.1745	0.2093	0.2440	0.2787	0.3134	0.3480	0.3826	0.4171	0.4517	0.4861	0.5206
24			0.1662	0.2076	0.2490	0.2904	0.3317	0.3729	0.4141	0.4553	0.4964	0.5375	0.5785	0.6195
26			0.1951	0.2437	0.2923	0.3408	0.3893	0.4377	0.4860	0.5344	0.5826	0.6308	0.6790	0.7271
28				0.2826	0.3390	0.3952	0.4514	0.5076	0.5637	0.6197	0.6757	0.7316	0.7874	0.8432
30				0.3244	0.3891	0.4537	0.5182	0.5827	0.6471	0.7114	0.7757	0.8398	0.9040	0.9680
32				0.3691	0.4427	0.5162	0.5896	0.6630	0.7363	0.8094	0.8825	0.9556	1.0285	1.1014
34				0.4167	0.4998	0.5828	0.6657	0.7485	0.8312	0.9138	0.9963	1.0787	1.1611	1.2433
36				0.4672	0.5603	0.6533	0.7463	0.8391	0.9318	1.0244	1.1170	1.2094	1.3017	1.3939
38				0.5205	0.6243	0.7280	0.8315	0.9349	1.0382	1.1414	1.2445	1.3475	1.4503	1.5531
40					0.6918	0.8066	0.9213	1.0359	1.1504	1.2647	1.3790	1.4931	1.6070	1.7209
42					0.7627	0.8893	1.0158	1.1421	1.2683	1.3944	1.5203	1.6461	1.7718	1.8973
44					0.8370	0.9760	1.1148	1.2535	1.3920	1.5303	1.6685	1.8066	1.9445	2.0823
46						1.0667	1.2185	1.3700	1.5214	1.6726	1.8237	1.9746	2.1253	2.2759
48							1.3267	1.4917	1.6566	1.8212	1.9857	2.1500	2.3141	2.4781
50							1.4396	1.6186	1.7975	1.9762	2.1546	2.3329	2.5110	2.6889
52							1.5570	1.7507	1.9442	2.1374	2.3305	2.5233	2.7159	2.9083
54								1.8880	2.0966	2.3050	2.5132	2.7211	2.9288	3.1363
56								2.0304	2.2548	2.4789	2.7028	2.9264	3.1498	3.3729
58									2.4187	2.6591	2.8993	3.1392	3.3788	3.6182
60									2.5884	2.8457	3.1027	3.3594	3.6158	3.8720
62									2.7638	3.0385	3.3130	3.5871	3.8609	4.1344
64									2.9450	3.2377	3.5302	3.8222	4.1140	4.4055
66									3.1320	3.4433	3.7542	4.0649	4.3752	4.6851
68									3.3246	3.6551	3.9852	4.3150	4.6443	4.9734
70										3.8733	4.2231	4.5725	4.9215	5.2702
72											4.4678	4.8375	5.2068	5.5757
74											4.7195	5.1100	5.5001	5.8897

Honer's (1983) Total cubic metre volume equation

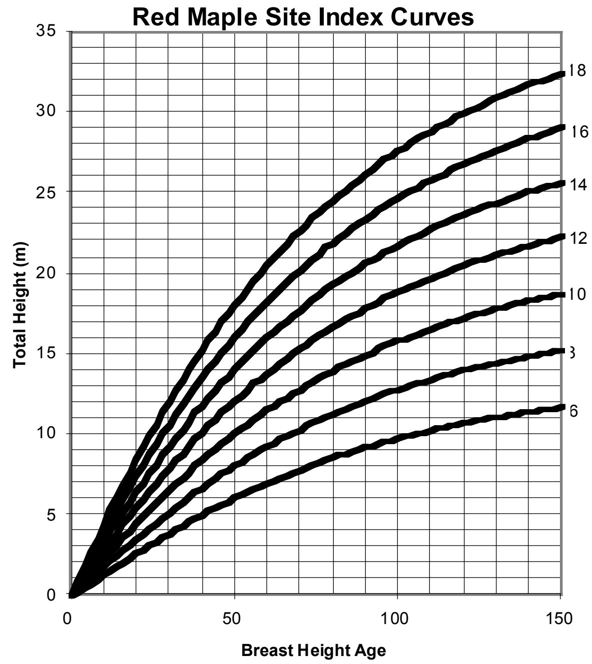
Volume (m^3) = 0.0043891*dbh^2 * (1-0.04365*0.145)^2 / (0.033+(0.3048*393.336/Height))   +/- 13+/- 19.8 % Accuracy

21 Trees

APPENDIX D

Red Maple Growth & Yield Factsheet

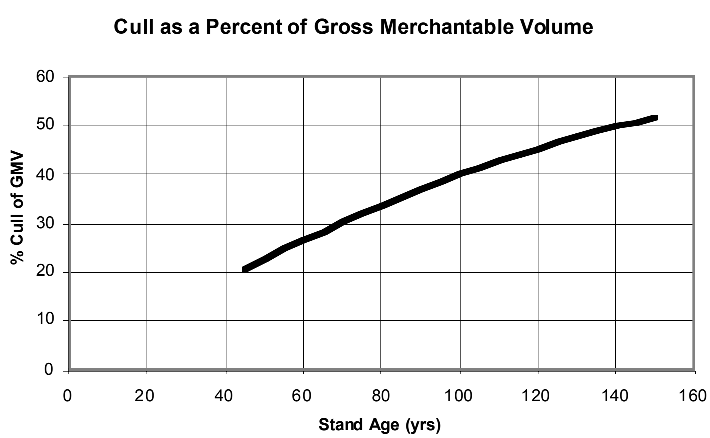
Age	Site Index 6	8	10	12	14	16	18
5	0.5	0.8	1.0	1.3	1.6	1.9	2.1
10	1.2	1.7	2.2	2.7	3.2	3.8	4.3
15	1.9	2.6	3.3	4.1	4.8	5.6	6.4
20	2.5	3.5	4.4	5.4	6.4	7.4	8.4
25	3.2	4.3	5.5	6.7	7.8	9.0	10.2
30	3.8	5.1	6.5	7.9	9.2	10.6	12.0
35	4.4	5.9	7.4	9.0	10.5	12.1	13.6
40	5.0	6.6	8.3	10.1	11.8	13.5	15.2
45	5.5	7.3	9.2	11.1	12.9	14.8	16.6
50	6.0	8.0	10.0	12.0	14.0	16.0	18.0
55	6.5	8.6	10.8	12.9	15.0	17.1	19.3
60	6.9	9.2	11.5	13.8	16.0	18.2	20.5
65	7.4	9.7	12.1	14.5	16.9	19.2	21.6
70	7.8	10.3	12.8	15.3	17.7	20.2	22.6
75	8.1	10.7	13.3	16.0	18.5	21.0	23.6
80	8.5	11.2	13.9	16.6	19.2	21.9	24.5
85	8.8	11.6	14.4	17.2	19.9	22.6	25.3
90	9.1	12.0	14.9	17.8	20.5	23.3	26.1
95	9.4	12.4	15.3	18.3	21.1	24.0	26.9
100	9.7	12.7	15.7	18.8	21.7	24.6	27.6
105	10.0	13.1	16.1	19.2	22.2	25.2	28.2
110	10.2	13.4	16.5	19.7	22.7	25.8	28.8
115	10.4	13.7	16.9	20.1	23.2	26.3	29.4
120	10.6	13.9	17.2	20.4	23.6	26.7	29.9
125	10.8	14.2	17.5	20.8	24.0	27.2	30.4
130	11.0	14.4	17.8	21.1	24.3	27.6	30.8
135	11.2	14.6	18.0	21.4	24.7	28.0	31.3
140	11.3	14.8	18.3	21.7	25.0	28.3	31.6
145	11.5	15.0	18.5	22.0	25.3	28.7	32.0
150	11.6	15.2	18.7	22.2	25.6	29.0	32.4



$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048\wedge b5)}]*.3048$						R^2	SE	Maximum difference
	b_1	b_2	b_3	b_4	b_5			
Ht	2.9435	0.9132	-0.0141	1.6580	-0.1095	0.99	0.15	0.6
SI	0.3263	1.0634	-0.0106	-1.2573	-0.0646	0.99	0.16	0.7

Data Source: Carmean 1978

Northern Wisconsin and Upper Michigan. 114 Plots having 438 dominant and codominant trees. Stem analysis, nonlinear regression, polymorphic. Add 4 years to obtain total age.



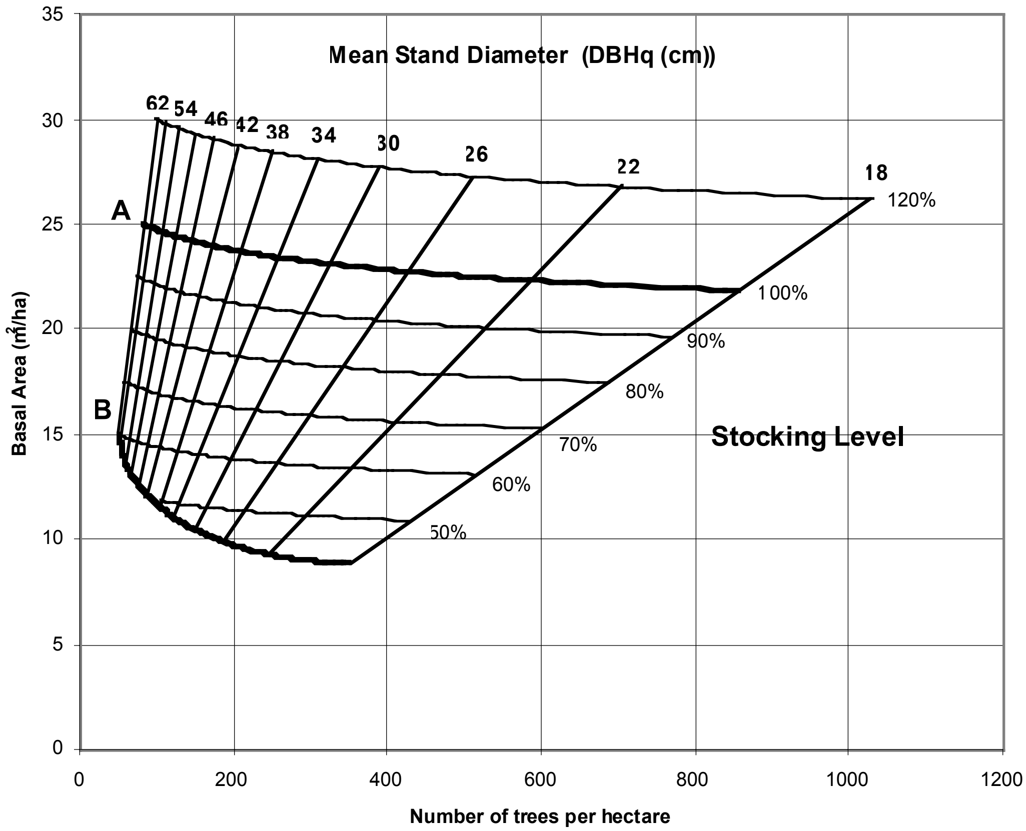
Cull = -0.0011 * Stand Age^2 + 0.5101 * Stand Age

Data Source: Basham, J.T. 1991. 66 trees

Cull as a % of Gross Merchantable Volume

Age	%	Age	%
20	9.76	105	41.43
25	12.07	110	42.80
30	14.31	115	44.11
35	16.51	120	45.37
40	18.64	125	46.58
45	20.73	130	47.72
50	22.76	135	48.82
55	24.73	140	49.85
60	26.65	145	50.84
65	28.51	150	51.77
70	30.32		
75	32.07		
80	33.77		
85	35.41		
90	37.00		
95	38.53		
100	40.01		

Red Maple Stocking Guide



(Erdman et al. 1985)

	120%		A Line		90%		80%		60%		50%	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
18	1029	26.2	858	21.8	772	19.6	686	17.5	515	13.1	429	10.9
22	704	26.8	587	22.3	528	20.1	470	17.8	352	13.4	293	11.2
26	514	27.3	428	22.7	385	20.4	342	18.2	257	13.6	214	11.4
30	392	27.7	327	23.1	294	20.8	261	18.5	196	13.8	163	11.5
34	309	28.1	258	23.4	232	21.1	206	18.7	155	14.0	129	11.7
38	251	28.4	209	23.7	188	21.3	167	19.0	125	14.2	104	11.8
42	208	28.7	173	24.0	156	21.6	138	19.2	104	14.4	86	12.0
46	175	29.0	146	24.2	131	21.8	116	19.4	87	14.5	73	12.1
50	149	29.3	124	24.4	112	22.0	100	19.5	75	14.6	62	12.2
54	129	29.5	108	24.6	97	22.2	86	19.7	65	14.8	54	12.3
58	113	29.8	94	24.8	85	22.3	75	19.9	56	14.9	47	12.4
62	99	30.0	83	25.0	75	22.5	66	20.0	50	15.0	41	12.5

Maple Standard Volume Table (m^3)*

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0143	0.0211	0.0276	0.0340	0.0401	0.0461	0.0518	0.0574	0.0628	0.0681	0.0732	0.0781	0.0829	0.0876
12	0.0206	0.0304	0.0398	0.0489	0.0578	0.0663	0.0746	0.0827	0.0905	0.0980	0.1054	0.1125	0.1194	0.1261
14	0.0280	0.0413	0.0542	0.0666	0.0787	0.0903	0.1016	0.1125	0.1231	0.1334	0.1434	0.1531	0.1625	0.1717
16	0.0366	0.0540	0.0708	0.0870	0.1027	0.1180	0.1327	0.1470	0.1608	0.1743	0.1873	0.2000	0.2123	0.2243
18	0.0463	0.0683	0.0896	0.1101	0.1300	0.1493	0.1679	0.1860	0.2036	0.2206	0.2371	0.2531	0.2687	0.2838
20	0.0572	0.0843	0.1106	0.1360	0.1605	0.1843	0.2073	0.2297	0.2513	0.2723	0.2927	0.3125	0.3317	0.3504
22	0.0692	0.1021	0.1338	0.1645	0.1942	0.2230	0.2509	0.2779	0.3041	0.3295	0.3542	0.3781	0.4014	0.4240
24	0.0824	0.1215	0.1592	0.1958	0.2312	0.2654	0.2986	0.3307	0.3619	0.3921	0.4215	0.4500	0.4777	0.5046
26		0.1425	0.1869	0.2298	0.2713	0.3115	0.3504	0.3881	0.4247	0.4602	0.4947	0.5281	0.5606	0.5922
28		0.1653	0.2168	0.2665	0.3146	0.3612	0.4064	0.4501	0.4926	0.5337	0.5737	0.6125	0.6502	0.6868
30			0.2488	0.3059	0.3612	0.4147	0.4665	0.5167	0.5655	0.6127	0.6586	0.7031	0.7464	0.7884
32				0.3481	0.4109	0.4718	0.5308	0.5879	0.6434	0.6971	0.7493	0.8000	0.8492	0.8970
34				0.3929	0.4639	0.5326	0.5992	0.6637	0.7263	0.7870	0.8459	0.9031	0.9587	1.0127
36					0.5201	0.5971	0.6718	0.7441	0.8143	0.8823	0.9483	1.0125	1.0748	1.1353
38					0.5795	0.6653	0.7485	0.8291	0.9072	0.9831	1.0566	1.1281	1.1975	1.2649
40					0.6421	0.7372	0.8294	0.9187	1.0052	1.0893	1.1708	1.2500	1.3269	1.4016
42						0.8128	0.9144	1.0128	1.1083	1.2009	1.2908	1.3781	1.4629	1.5453
44						0.8920	1.0035	1.1116	1.2164	1.3180	1.4167	1.5125	1.6055	1.6959
46						0.9750	1.0968	1.2149	1.3294	1.4405	1.5484	1.6531	1.7548	1.8536
48						1.0616	1.1943	1.3229	1.4476	1.5685	1.6859	1.7999	1.9107	2.0183
50						1.1519	1.2959	1.4354	1.5707	1.7020	1.8294	1.9531	2.0732	2.1900
52						1.2459	1.4016	1.5525	1.6989	1.8408	1.9786	2.1124	2.2424	2.3687
54						1.3436	1.5115	1.6743	1.8321	1.9852	2.1338	2.2781	2.4182	2.5544
56						1.4449	1.6255	1.8006	1.9703	2.1349	2.2948	2.4499	2.6007	2.7471
58								1.9315	2.1135	2.2902	2.4616	2.6280	2.7897	2.9469
60								2.0670	2.2618	2.4508	2.6343	2.8124	2.9854	3.1536
62								2.2071	2.4151	2.6169	2.8128	3.0030	3.1878	3.3674
64									2.5734	2.7885	2.9972	3.1999	3.3968	3.5881
66										2.9655	3.1875	3.4030	3.6124	3.8159
68										3.1480	3.3836	3.6124	3.8346	4.0506
70										3.3358	3.5855	3.8280	4.0635	4.2924
72										3.5292	3.7934	4.0499	4.2990	4.5412
74										3.7280	4.0070	4.2780	4.5412	4.7970

Honer's (1967) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.145)^2 / (1.046+(0.3048*383.972/Height))$ +/- 30.3% Accuracy

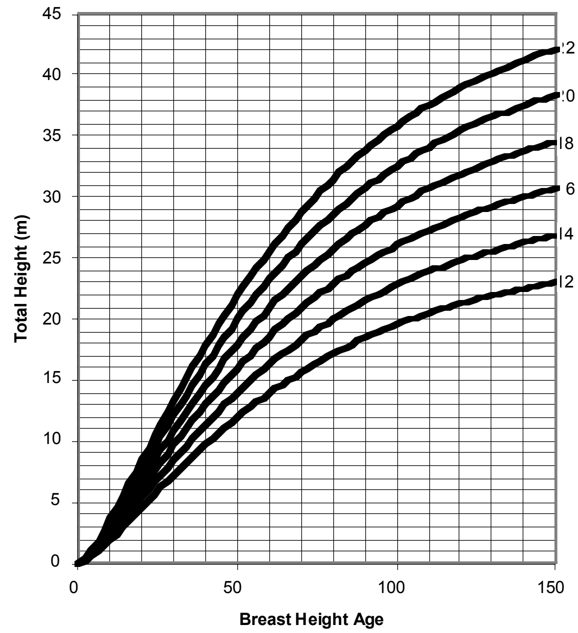
* Volume table includes Hard and Red maple 3967 Trees

——— Denotes range of data

Eastern Hemlock Growth & Yield Factsheet

	Site Index					
Age	**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

Hemlock Site Index Curves

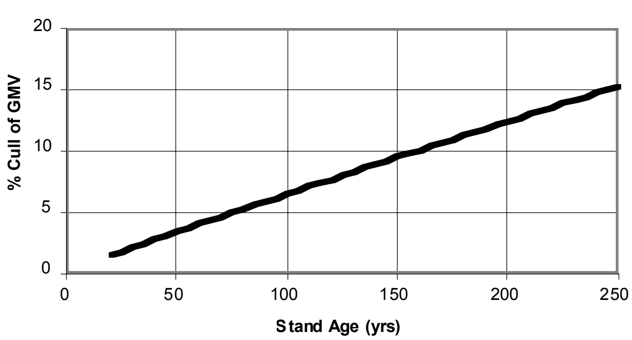


Ht=[b1*(SI*.3048^b2)*(1-EXP^b3 *Age)^b4 *(SI*.3048^b5)] *.3048					R^2	SE	Maximum
	b_1	b_2	b_3	b_4	b_5			difference
Ht	2.1419	0.9979	-0.0175	1.4086	-0.0008	0.99	0.15	0.5
SI	0.2172	1.1309	-0.0105	-1.9120	-0.1327	0.99	0.37	1.0

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 as a Percent of Gross Merchantable Volume

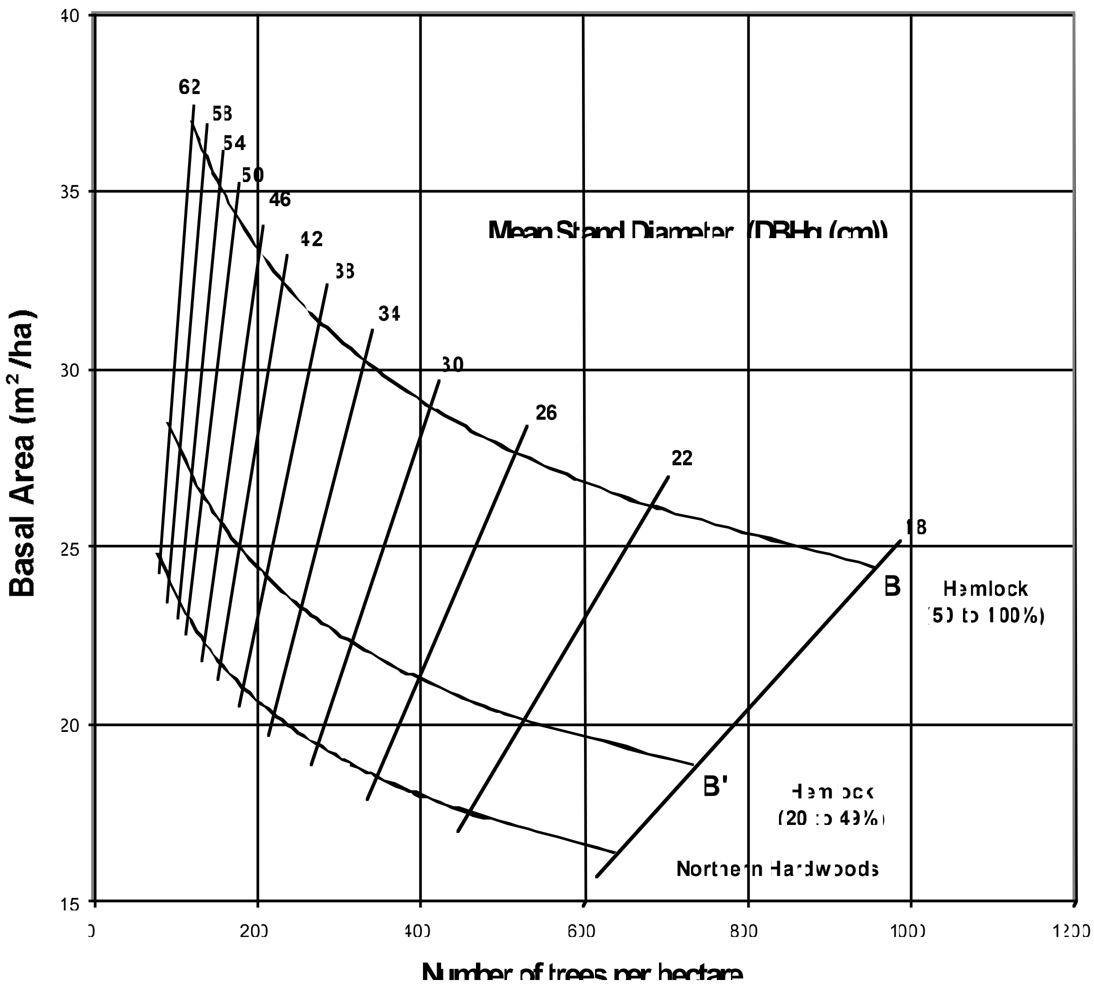


Cull = = 0.0892 * Stand Age$^{0.9326}$

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 m²/ha**	**Trees #/ha**	**BA m²/ha**	**Trees #/ha**	**BA m²/ha**
18	957	24.4	737	18.8	641	16.3
22	636	26.1	528	20.1	459	17.5
26	519	27.6	400	21.2	348	18.5
30	409	28.9	315	22.3	274	19.4
34	333	30.2	256	23.2	223	20.2
38	276	31.3	213	24.1	185	21.0
42	234	32.4	180	25.0	157	21.7
46	201	33.4	155	25.7	135	22.4
50	175	34.4	135	26.5	117	23.0
54	154	35.3	119	27.2	103	23.6
58	137	36.1	105	27.8	92	24.2
62	123	36.9	94	28.4	82	24.8

Eastern Hemlock Standard Volume Table (m^3)

Dbh	Total Tree Height (m)													
(cm)	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

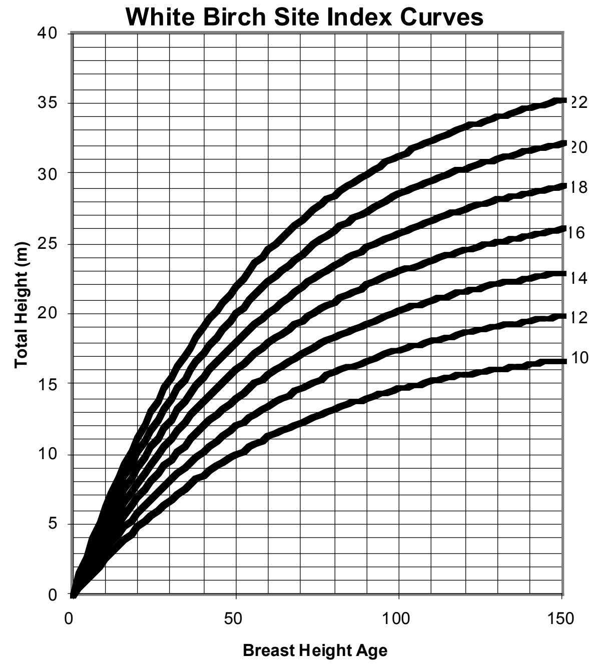
Honer's (1967) Total cubic metre volume equation

Volume (m^3) = 0.0043891*dbh^2 * (1-0.04365*0.155)^2 / (1.112+(0.3048*350.092/Height)) +/- 23.6% Accuracy

——— Denotes range of data 383 Trees

White Birch Growth & Yield Factsheet

Age	Site Index 10	12	14	16	18	20	22
5	1.3	1.6	1.9	2.2	2.6	2.9	3.2
10	2.5	3.1	3.7	4.3	4.9	5.5	6.2
15	3.7	4.5	5.4	6.2	7.1	7.9	8.8
20	4.8	5.8	6.9	8.0	9.0	10.1	11.2
25	5.8	7.1	8.3	9.6	10.9	12.1	13.4
30	6.8	8.2	9.7	11.1	12.5	14.0	15.4
35	7.7	9.3	10.9	12.5	14.1	15.7	17.3
40	8.5	10.3	12.0	13.8	15.5	17.2	19.0
45	9.3	11.2	13.0	14.9	16.8	18.7	20.6
50	10.0	12.0	14.0	16.0	18.0	20.0	22.0
55	10.7	12.8	14.9	17.0	19.1	21.2	23.3
60	11.3	13.5	15.7	17.9	20.1	22.3	24.5
65	11.8	14.1	16.4	18.7	21.0	23.3	25.6
70	12.3	14.7	17.1	19.5	21.9	24.3	26.7
75	12.8	15.3	17.8	20.2	22.7	25.1	27.6
80	13.2	15.8	18.3	20.9	23.4	25.9	28.5
85	13.6	16.3	18.9	21.5	24.1	26.7	29.2
90	14.0	16.7	19.4	22.0	24.7	27.3	30.0
95	14.3	17.1	19.8	22.5	25.3	28.0	30.6
100	14.7	17.4	20.2	23.0	25.8	28.5	31.3
105	14.9	17.8	20.6	23.4	26.3	29.0	31.8
110	15.2	18.1	21.0	23.8	26.7	29.5	32.3
115	15.5	18.4	21.3	24.2	27.1	30.0	32.8
120	15.7	18.6	21.6	24.5	27.5	30.4	33.3
125	15.9	18.9	21.9	24.8	27.8	30.7	33.7
130	16.1	19.1	22.1	25.1	28.1	31.1	34.0
135	16.2	19.3	22.4	25.4	28.4	31.4	34.4
140	16.4	19.5	22.6	25.6	28.7	31.7	34.7
145	16.6	19.7	22.8	25.8	28.9	31.9	35.0
150	16.7	19.8	23.0	26.0	29.1	32.2	35.2

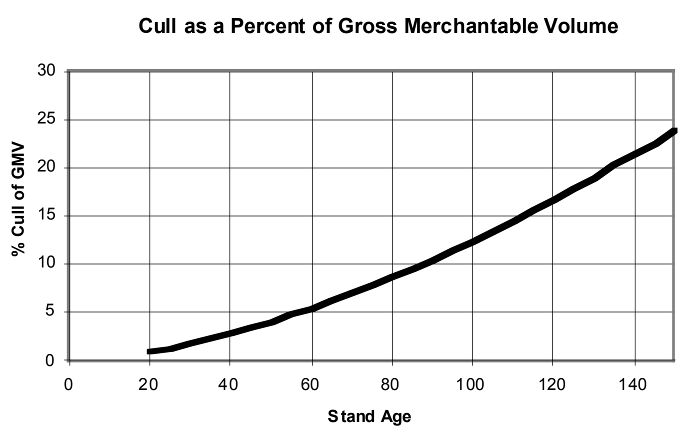


$Ht=[b1*(SI*.3048^{b2})*(1-EXP^{b3*Age})^{b4*(SI*.3048^{\wedge}b5)}]*.3048$

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
Ht	2.4321	0.9207	-0.0168	1.5297	-0.1042	0.99	0.49	0.4
SI	0.5119	1.0229	-0.0167	-1.0284	-0.0049	0.99	0.33	1.3

Data Source: Carmean 1978

Lake States Data. Number of trees used for equation derivation unknown.
Add 4 Years to breast-height age to get total age.



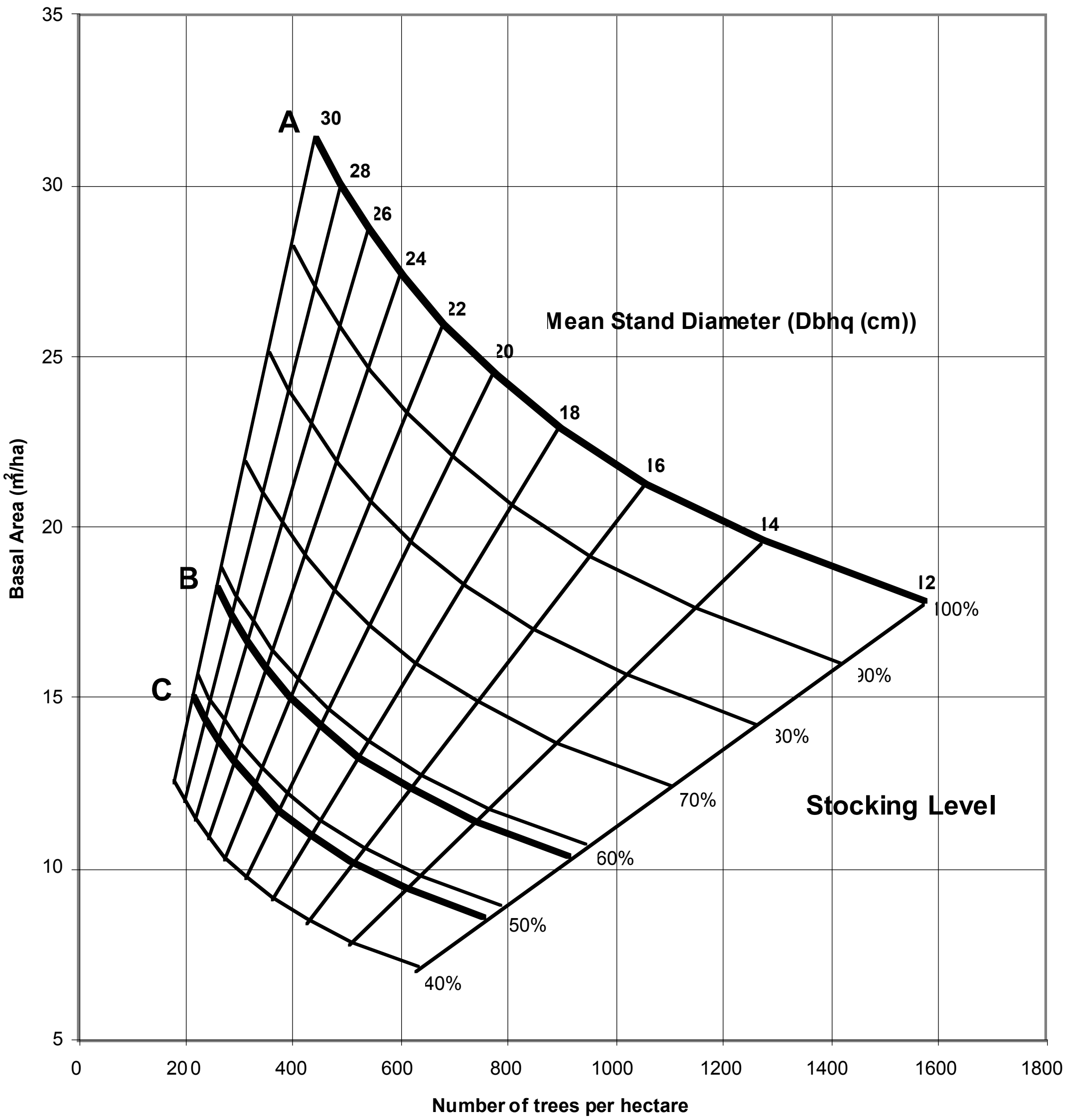
Cull = 0.007 * Stand Age$^{1.624}$

Data Source: Basham, J.T. 1991. 936 trees from the Boreal forest

Cull as a % of Gross Merchantable Volume

Age	%	Age	%	Age	%
20	0.91	54	4.56	88	5.70
22	1.06	56	4.83	90	5.97
24	1.22	58	5.12	95	6.71
26	1.39	60	5.41	100	7.50
28	1.57	62	5.70	105	8.36
30	1.75	64	6.00	110	9.27
32	1.95	66	6.31	115	10.25
34	2.15	68	6.62	120	11.29
36	2.36	70	6.94	125	12.38
38	2.57	72	7.27	130	13.54
40	2.80	74	7.60	135	14.75
42	3.03	76	7.93	140	16.03
44	3.27	78	8.28	145	17.36
46	3.51	80	8.62	150	18.76
48	3.76	82	8.98		
50	4.02	84	9.34		
52	4.28	86	9.70		

White Birch Stocking Guide



(from Marquis et al., 1989)

	A Line		90%		80%		70%		B Line		50%		C Line	
DBHq (cm)	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha	Trees # ha	BA m^2/ha
12	1574	17.8	1417	16.0	1259	14.2	1102	12.5	913	10.3	787	8.9	755	8.5
14	1272	19.6	1145	17.6	1018	15.7	890	13.7	738	11.4	636	9.8	611	9.4
16	1058	21.3	952	19.1	846	17.0	740	14.9	613	12.3	529	10.6	508	10.2
18	899	22.9	809	20.6	719	18.3	629	16.0	521	13.3	449	11.4	431	11.0
20	777	24.4	699	22.0	622	19.5	544	17.1	451	14.2	389	12.2	373	11.7
22	681	25.9	613	23.3	545	20.7	477	18.1	395	15.0	341	12.9	327	12.4
24	604	27.3	544	24.6	483	21.9	423	19.1	350	15.9	302	13.7	290	13.1
26	541	28.7	487	25.8	433	23.0	379	20.1	314	16.7	270	14.4	260	13.8
28	488	30.1	439	27.1	391	24.0	342	21.0	283	17.4	244	15.0	234	14.4
30	444	31.4	399	28.2	355	25.1	311	22.0	257	18.2	222	15.7	213	15.1

White Birch Standard Volume Table (m^3)

Dbh (cm)	Total Tree Height (m) 4	6	8	10	12	14	16	18	20	22	24	26	28	30
10	0.0172	0.0247	0.0316	0.0380	0.0439	0.0493	0.0544	0.0591	0.0636	0.0677	0.0716	0.0753	0.0787	0.0820
12	0.0248	0.0356	0.0455	0.0547	0.0632	0.0710	0.0783	0.0852	0.0915	0.0975	0.1031	0.1084	0.1133	0.1180
14	0.0337	0.0485	0.0620	0.0745	0.0860	0.0967	0.1066	0.1159	0.1246	0.1327	0.1403	0.1475	0.1542	0.1606
16	0.0441	0.0633	0.0810	0.0972	0.1123	0.1263	0.1393	0.1514	0.1627	0.1733	0.1833	0.1926	0.2015	0.2098
18	0.0558	0.0801	0.1025	0.1231	0.1421	0.1598	0.1763	0.1916	0.2059	0.2194	0.2320	0.2438	0.2550	0.2655
20		0.0989	0.1265	0.1519	0.1755	0.1973	0.2176	0.2365	0.2542	0.2708	0.2864	0.3010	0.3148	0.3278
22		0.1197	0.1531	0.1839	0.2123	0.2387	0.2633	0.2862	0.3076	0.3277	0.3465	0.3642	0.3809	0.3966
24			0.1822	0.2188	0.2527	0.2841	0.3134	0.3406	0.3661	0.3900	0.4124	0.4334	0.4533	0.4720
26			0.2138	0.2568	0.2966	0.3335	0.3678	0.3998	0.4297	0.4577	0.4840	0.5087	0.5320	0.5540
28				0.2978	0.3439	0.3867	0.4265	0.4636	0.4983	0.5308	0.5613	0.5900	0.6170	0.6425
30				0.3419	0.3948	0.4440	0.4896	0.5322	0.5720	0.6093	0.6443	0.6773	0.7083	0.7376
32				0.3890	0.4492	0.5051	0.5571	0.6056	0.6509	0.6933	0.7331	0.7706	0.8059	0.8392
34				0.4391	0.5071	0.5702	0.6289	0.6836	0.7348	0.7827	0.8276	0.8699	0.9097	0.9474
36				0.4923	0.5686	0.6393	0.7051	0.7664	0.8237	0.8774	0.9279	0.9753	1.0199	1.0621
38				0.5485	0.6335	0.7123	0.7856	0.8539	0.9178	0.9776	1.0338	1.0866	1.1364	1.1834
40					0.7019	0.7893	0.8705	0.9462	1.0170	1.0833	1.1455	1.2040	1.2592	1.3112
42					0.7739	0.8702	0.9597	1.0432	1.1212	1.1943	1.2629	1.3274	1.3882	1.4456
44					0.8493	0.9550	1.0533	1.1449	1.2305	1.3108	1.3861	1.4569	1.5236	1.5866
46						1.0438	1.1512	1.2513	1.3449	1.4326	1.5149	1.5923	1.6653	1.7341
48							1.2535	1.3625	1.4644	1.5599	1.6495	1.7338	1.8132	1.8882
50							1.3601	1.4784	1.5890	1.6926	1.7898	1.8813	1.9675	2.0488
52							1.4711	1.5991	1.7187	1.8307	1.9359	2.0348	2.1280	2.2160
54								1.7244	1.8534	1.9743	2.0877	2.1943	2.2948	2.3897
56								1.8545	1.9933	2.1232	2.2452	2.3599	2.4680	2.5700
58									2.1382	2.2776	2.4084	2.5315	2.6474	2.7568
60									2.2882	2.4374	2.5774	2.7091	2.8331	2.9502
62									2.4433	2.6026	2.7521	2.8927	3.0252	3.1502
64									2.6034	2.7732	2.9325	3.0823	3.2235	3.3567
66									2.7687	2.9492	3.1186	3.2780	3.4281	3.5698
68									2.9390	3.1306	3.3105	3.4796	3.6390	3.7894
70										3.3175	3.5081	3.6873	3.8562	4.0156
72											3.7114	3.9010	4.0797	4.2483
74											3.9205	4.1208	4.3095	4.4876

Honer's (1983) Total cubic metre volume equation

Volume (m^3) = $0.0043891 * dbh^2 * (1-0.04365*0.176)^2 / (2.222+(0.3048*300.373/Height))$

+/- 22.5 % Accuracy

1272 Trees

APPENDIX D

APPENDIX E

How To Use A Stocking Guide

How to Use a Stocking Guide

Stocking guides are decision support tools used in even-aged management to show the relationship between the number of trees and basal area, stocking per cent and quadratic mean diameter for trees in the stand. These guides provide an assessment of the stand's use of available growing space and suggests when growing space is limited and thinnings should be considered to meet management objectives (usually this means to maintain optimum growth).

When using a stocking guide make sure that you are using one that is most appropriate for your stand condition. Species and site factors influence the development of local stocking guides. APPENDIX D provides examples of stocking guides that are appropriate for most species in Ontario. Where stocking guides have not been created for an individual species or where local site conditions are different from where the stocking guide was created, it is recommended that those developed by Leak *et al.* (1987) or Tubbs (1977b) be used.

Stocking guides are simply graphs with the number of trees per area on the X-axis and basal area per area on the Y-axis (***see*** FIGURE 7.5.1). On the graph there are also 2 series of lines that show the quadratic mean diameter for trees in the stand and the level of stocking. Stocking levels are usually presented as "A", "B" and "C" lines. The "A" line represents the normal condition of maximum stocking for undisturbed stands of average structure. At this line the stand is fully utilizing or occupying the site. The "B" line is the lower limit of stocking needed for full occupancy of the site. This is where crowns are fully developed and are just touching each other. crowns. In general for tolerant hardwoods, the "B" is approximately 58 per cent of the "A" line level. Stands at "C"-level stocking are expected to reach the "B" level within 10 years (Gingrich 1967).

The stocking guides developed by Gingrich (1967) for upland hardwoods in the central United States have been adapted to meet local stand and site conditions, stocking standards and management objectives.

Tubbs (1977b) developed a stocking guide for site conditions and management objectives in the Lakes States. He replaced the "A", "B" and "C" lines with "maximum", "average" and "minimum" stocking levels for optimum growth in the Lake States. These lines represent 110 per cent, 100 per cent and 90 per cent crown canopy closure levels.

Leak *et al.* (1987) produced a stocking guide for beech-red maple and beech-birch-maple stands in New England. The "A"-level represents 142 per cent crown canopy closure and the "B"-level 90 per cent.

The number of trees and basal area per hectare is needed to use a stocking guide. Stand stocking level and quadratic mean diameter are determined by the intersection of stand density and basal area. From this location the crown cover can be determined.

When stocking is at the “A” level , the stand is fully stocked and growing space is fully utilized. If it is above the “A” level, growing space is over-utilized and there will be mortality and self-thinning. In this condition, individual tree and stand growth is low and individual tree mortality offsets growth to keep stocking at the “A”-level. Growing space is also fully utilized between “A”- and “B”-level stocking. Stands grow, but growth on individual trees varies greatly. Below “B”-level stocking, growing space is not fully utilized and optimum use of the resources does not occur.

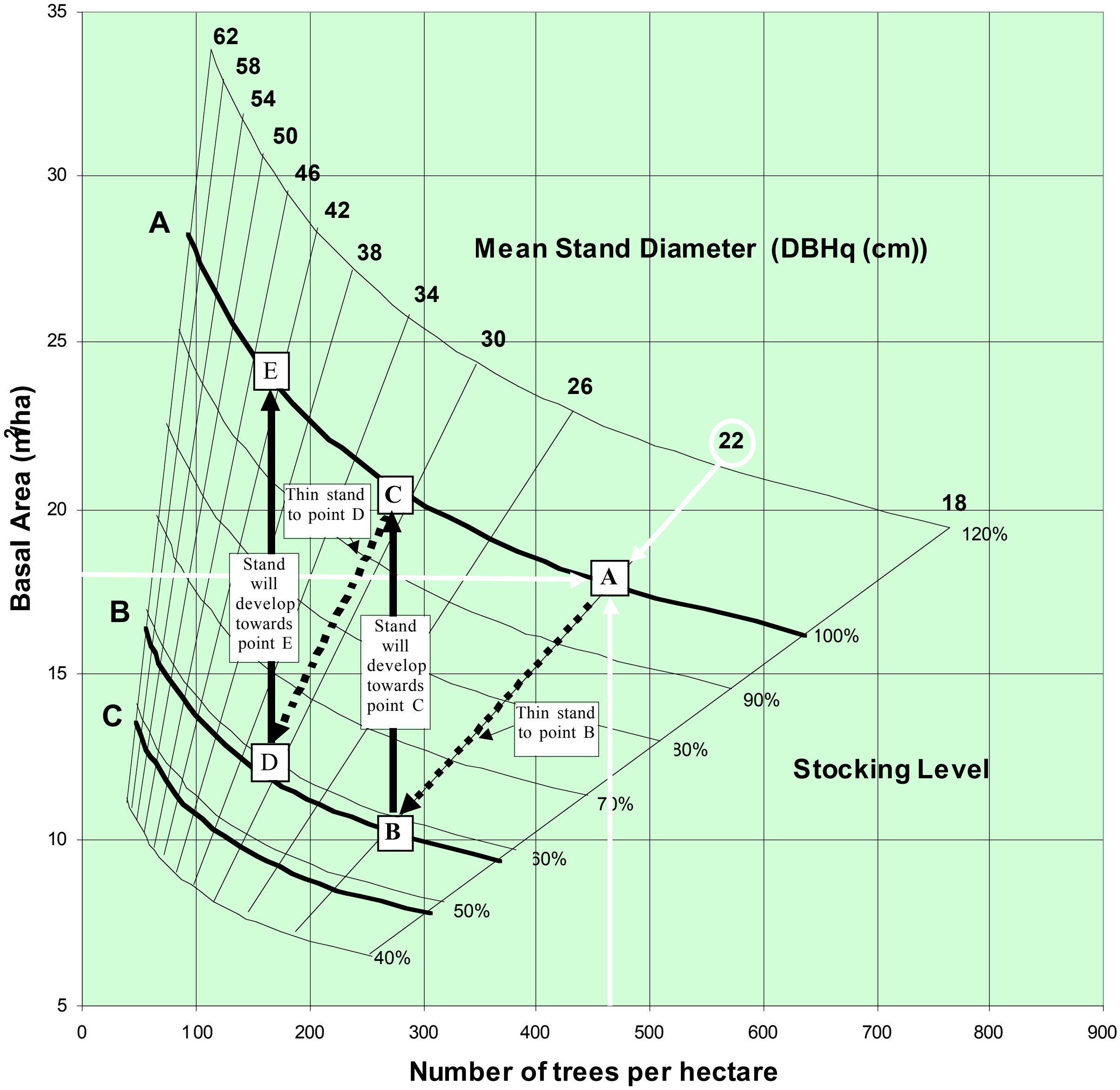
Thinning is recommended in stands that are at or above the “A”-level. Individual tree growth is highest when the stand is thinned to the “B”-level. In thinning the stand, the number of trees and basal area will be lowered, but the quadratic mean diameter of the stand should remain roughly the same or increase if thinning removes the smaller diameter trees. Changes in stand conditions can be projected by moving down the appropriate quadratic mean diameter line to the post harvest density level. Growth can be predicted by moving the stand parallel to the Y-axis. (i.e. the number of trees remains the same, but as trees grow the basal area will increase). Thinning should be scheduled again when stands reach the “A”-level, if maximizing tree growth is a main objective.

Thinning stands between the “A”- and “B”-levels, to the “B”-level may increase individual tree growth but at the expense of overall stand growth. Thinning in this zone is done to meet non-timber management objectives.

Stands below the “B”-level should not be thinned.

In the example shown below the current stand condition is identified at point A. It is positioned at the 100% stocking level (“A” line). At this level a thinning is prescribed. The stand is thinned to position B (the “B” line). This lowers the basal area and the number of trees by maintaining the mean stand diameter (DBHq). Trees remaining in the stand at point B will grow to point C (100% stocking level). This process is repeated again where trees are thinned from point C to point D. Trees remaining grow from point D to point E.

Example application of a stocking guide



SUMMARY TABLE			
Point	**Basal Area (m^2/ha)**	**Number of trees/ha**	**DBHq (cm)**
A	18	475	22
B	11	280	22
C	21	280	31
D	12	160	31
E	24	160	44

APPENDIX F

Silvicultural Option Tables

Silvicultural Option Tables

by Al Corlett and Brian Batchelor

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, 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 specific 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 or in a specific treatment package 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 that ecosite.

Note: Silvicultural options are described individually. They may be used alone (e.g. a uniform shelterwood harvest may be the only treatment prescribed). They may also be used in combination. For example a uniform shelterwood harvest may require subsequent mechanical site preparation and seeding in order that the silvicultural objective may be met.

Protection options are not listed in these tables. Forest managers are advised to consider the use of appropriate silvicultural treatments to prevent damage from occurring.

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 will be instances where tolerant hardwoods may be managed on conifer or intolerant hardwood ecosites, situations for which silvicultural option tables have not been specifically developed for this guide.

For example, abundant tolerant hardwood regeneration may be encountered on a poplar / white birch dominated ecosite (i.e. ES 17.2). The manager could choose to manage for tolerant hardwood on such an ecosite if that is determined to be a desirable long-term objective based on site potential and the current understanding of naturally occurring disturbance patterns and successional trends. In such a case, it would be appropriate for the manager to use the treatments listed for ES 27, an ecosite with similar conditions for which tolerant hardwood management is one of the identified objectives. Similarly, managers dealing with a comparable situation on a conifer dominated ecosite would apply the management options identified for ES 23.

SILVICULTURAL OPTIONS FOR ECO-SITE 23.1

Red Oak / Hardwood on Dry to Moderately Fresh Soils

Summary of ecosite features: Or is the dominant species in this ecosite followed by Mh, and then lesser proportions of Pg, Pw, Bw and He. There are high levels of regeneration in the understory, principally Mh, Iw, B, Or, Ms and Aw. Most sites (>60 per cent) are very shallow to shallow with coarse textured soil. On the shallow and drier sites, Mh and Be quality potential will decline to a much greater extent than that of the Or or Pw.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-system of choice in situations of higher Or / Pw / Aw composition where regeneration to mid-tolerants is the principal objective, or -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1).
SELECTION		
Single Tree	CR	-applicable in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Most appropriate on moderately fresh sites which are already dominated by Mh, and capable of supporting the selection system.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Or (and Bd or Aw on moderately fresh sites)) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-post-harvest SIP which removes tolerant hardwood competition and buries acorns may be appropriate, although technique may remove Or advance growth if present. -fine textured soils with <30% coarse fragments are prone to compaction when wet. -may be prone to erosion if large continuous area exposed during SIP.
Chemical	CR	-this ecosite is less competition prone than 23.2, therefore chemical SIP following mechanical or prescribed fire may not be necessary.
Prescribed Fire	R	-advanced regeneration of Or will resprout while that of competing Mh and Iw will be set back. May create favourable seedbed conditions for associated Pw. Light fires greatly reduce but may not eliminate Pw advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Aw and Or. If mid-tolerant regeneration is desired, some post harvest treatment (i.e. PB) may be required.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory and post-harvest treatment will enhance chances of mid-tolerant representation as regeneration.
Seeding	CR	-procedures being tested for Or. Generally not required for Mh or most other related species assuming availability of seed producers, and normal seed crop frequency.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors, but desired species must be shielded from herbicide.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 23.2

Red Oak / Hardwood on Fresh to Moist Soils

Summary of ecosite features: Mh, Pg and Or are similar in terms of representation on this ecosite, each averaging 20 per cent of stand basal area. Ms, Bw, Be, Pt and Pw are lesser associates. High levels of hardwood regeneration in the understory, principally Mh, Iw, Ms, minor representation of Or. Soils are generally fresh, and >60 cm in depth, although 1/3 of sites are moist to very moist, with associated higher competition levels. Because of water availability and greater inherent fertility on many areas, this ecosite has potential to produce high quality sawlogs of most species, and also would support aggressive shade tolerant species such as Mh to the extent that efforts to attain regeneration of the mid-tolerants will be costly.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-system of choice if regeneration of the stand to a higher proportion of mid-tolerants is the objective, understanding that follow-up treatments will very likely be required, or -if AGS levels in overstory insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1), and regeneration establishment is the main objective.
SELECTION		
Single Tree	CR	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Aw regeneration may develop to some extent but will require timely release. Or representation will decline.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Or, Aw, Cb, Pw) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-post-harvest SIP which removes tolerant hardwood competition and buries acorns may be appropriate, although technique may remove Or advance growth if present. -will not benefit Mh regeneration effort. -slopes may limit coverage of treatment area. -fine textured soils with <30% coarse fragments are prone to compaction when wet.
Chemical	R	-may be required as component of Or regeneration establishment program
Prescribed Fire	R	-good candidate site for PB, however additional effort (planting or seeding) may be required either before or after the prescribed fire due to general lack of Or advance growth and abundance of Mh and Ms regeneration. -account for slope conditions during fire planning.
Regeneration		
Natural - advance growth	R	-high levels of Mh and Ms seed and sprout origin advance growth. Or advance growth may be present but generally a minor associate.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory and post-harvest treatment will enhance chances of mid-tolerant representation as regeneration.
Seeding	CR	-procedures being tested for Or. Generally not required for Mh or most other related species assuming availability of seed producers, and normal seed crop frequency.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors, but desired species must be protected.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 24.1

Sugar Maple / Red Oak / Basswood on Dry to Moderately Fresh Soils

Summary of ecosite features: Slightly higher representation of Or than Mh on average in this ecosite. Some stands or portions of stands may have a high representation of Bw, and lesser components of Pg, Bd, Aw and Be. There are high levels of regeneration in the understory, mainly Mh, Iw, Aw and Or. Most sites (>60 per cent) are very shallow to shallow. On the shallow and drier sites, Mh, Be, Bd and Aw quality potential will decline to a greater extent than that of the Or.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-in situations of higher Or / Aw composition when regeneration to mid-tolerants is the principal objective, or -if AGS levels insufficient for selection management (< $9m^2$/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	CR	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Most effective on moderately fresh sites. Or representation will decline.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Or (and Bd or Aw on moderately fresh sites)) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh, Be or Aw regeneration effort. Caution that technique may remove Or advance growth if present. -degree of slope may affect treatable area -site is moderately prone to compaction where <30% coarse fragments, some risk of erosion if continuos area of mineral soil exposure occur due to possible slope and soil texture conditions.
Chemical	CR	-will not benefit Mh or Aw regeneration effort, but may encourage Or by controlling advance growth of competing Mh. Or advance growth should be protected from herbicide.
Prescribed Fire	CR	-may encourage Or by controlling advance growth of competing Mh, but will not benefit Mh regeneration effort.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Aw and Or. Aw may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Generally not required for Mh or most other related species assuming availability of seed producers, and normal seed crop frequency.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors, but desired species must be shielded from herbicide.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 24.2
Sugar Maple / Red Oak / Basswood on Fresh to Moist Soils

Summary of ecosite features: Mh is the principal species on this ecosite with lesser representation of Or, Bd, Bw and Pw. There are high levels of hardwood regeneration, again dominated by Mh, but Iw, Or, Bd, B and Aw are represented as well. Soils are generally fresh, and >60 cm in depth. Because of water availability, this ecosite has potential to produce high quality sawlogs of most species, and also would support aggressive tolerants such as Mh to the extent that efforts to attain regeneration of the mid-tolerants will be costly.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-system of choice if regeneration to a higher proportion of mid-tolerants is the objective (supplementary silvicultural effort will be required to meet objective) or -if AGS levels in overstory insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	R	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Aw regeneration will develop as well to some extent but will require timely release if Aw component is an objective. Or representation will decline. Bd regeneration will decline moderately.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Bd, Or or Aw) in the stand. Or representation will decline unless commitment is made to tending.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh, Bd or Aw regeneration effort. If technique employed to encourage Or regeneration (removal of Mh competition, burying of acorns), follow-up chemical SIP or tending likely required. -slope may affect site preparation activities -some areas of fine textured soil and < 30% coarse fragments will be subject to compaction when wet.
Chemical	CR	-will not benefit Mh or Bd (or Aw) regeneration effort -may be required as component of Or regeneration establishment program
Prescribed Fire	CR	-fire may stimulate Bd coppice from seedlings, but will not benefit Mh regeneration effort. Operationally difficult to apply in Group Selection situations. May have application in Uniform Shelterwood situations.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Bd (often sprout origin). Or advance growth may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Generally not required for Mh or most other related species assuming availability of seed producers, and normal seed crop frequency.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 25.1

Sugar Maple / American Beech / Red Oak on Dry to Moderately Fresh Soils

Summary of ecosite features: Sugar maple usually the dominant overstory species, but both red oak and beech occasionally exceed 50 per cent of stand composition. White pine is an occasional component. High levels of hardwood regeneration, dominated by Mh, smaller components of Iw, Or, Be, Aw. Soils generally <60 cm. in depth, fine sandy to medium loamy. Quality and value potential of Or and Pw exceed that of other species on the drier sites.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	CR	-if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1), or -when regeneration to mid-tolerants is the principal objective (usually Or / Pw in drier areas, Bd and Aw on moderately fresh sites)
SELECTION		
Single Tree	R	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh, Be) regeneration. Most effective on moderately fresh sites.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Or and Pw (and Bd or Aw on moderately fresh sites)) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh, Be or Aw regeneration effort. Caution: may remove Or advance growth if present. May encourage Or regeneration by controlling advance growth of competing Be / Mh and burying acorns. -moderately prone to erosion where < 30% coarse fragments, some risk of erosion if continuous areas of mineral soil exposure occurs on slopes and when soils are coarse or silty, slope may limit choice and use of equipment.
Chemical	CR	-will not benefit Mh, Be or Aw regeneration effort, but may encourage Or by controlling advance growth of competing Be / Mh. Or advance growth should be protected from herbicide.
Prescribed Fire	CR	-will not benefit Mh or Be regeneration effort, but may encourage Or by controlling advance growth of competing Mh. Light fires greatly reduce but may not eliminate Pw advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Or. Aw may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Generally not required for Mh or most other related species assuming availability of seed producers, and normal seed crop frequency.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors, but desired species must be shielded.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 25.2

Sugar Maple / American Beech / Red Oak on Fresh to Moist Soils

Summary of ecosite features: Sugar maple usually the dominant overstory species. Beech, red oak and basswood average approximately 10 per cent of stand composition. White birch, white ash and hemlock are often present as well. High levels of hardwood regeneration, dominated by Mh, Iw and Be, with smaller components of Aw and Bd. Soils generally >60 cm. in depth, ranging from coarse loamy to silty. This ecosite has excellent potential to produce high quality hardwoods.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	CR	-if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1), or -stands having a high Or, He or Aw component, and objective to regenerate higher component of those species.
SELECTION		
Single Tree	R	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh, Be) regeneration. May be applied in He / Mh mixtures with modifications.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Bd, Or, or Aw) in the stand. Commitment to follow-up tending req'd to maintain Or component.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh, Be or Aw regeneration effort. Caution: may remove Or advance growth if present. May encourage Or regeneration by controlling advance growth of competing Be / Mh and burying acorns. -sites very prone to compaction where <30% coarse fragments and fine-textured soils; some risk of erosion if continuous areas of mineral soil exposure occur on slopes, and when soils are coarse or silty, slope may limit choice and use of equipment.
Chemical	CR	-will not benefit Mh or Aw regeneration effort, but may encourage Or by controlling advance growth of competing Be / Mh. Or advance growth should be protected from herbicide.
Prescribed Fire	CR	-will not benefit Mh regeneration effort, but may encourage Or by controlling advance growth of competing Mh.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Be. Aw may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Not required for Mh or most other related species.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 26.1

Sugar Maple / Basswood on Dry to Moderately Fresh Soils

Summary of ecosite features: Mh dominates the overstory and regeneration levels and will be a strong competitor following silvicultural intervention. Bd averages 20 per cent of stand composition, with minor representation of similarly mid-tolerant Aw and Or. On drier sites, Mh and Bd stem quality will decline, proportion and ease of establishment of Or and Aw will likely increase. Soils generally coarse textured, often moderately deep.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-applicable if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1), or -in situations of higher Bd / Or / Aw composition when regeneration to mid-tolerants is the principal objective. May stimulate Bd regeneration of seed origin.
SELECTION		
Single Tree	CR	-system of choice on moderately fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration, recognizing that mid-tolerant representation will decline.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood (primarily on moderately fresh sites), maintaining a component of mid-tolerants (Or (and Bd, Cb or Aw on moderately fresh sites)) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh, Bd or Aw regeneration effort. Some application where intent to reduce competing hardwoods, and to bury acorns, although limited opportunities for Or management on this ecosite. -moderately prone to erosion where < 30% coarse fragments, some risk of erosion if continuous areas of mineral soil exposure occurs on slopes and when soils are coarse or silty. Slope may limit choice and use of equipment.
Chemical	CR	-will not benefit Mh, Aw or Bd regeneration effort, but may encourage Or by controlling advance growth of competing Be / Mh. Or advance growth must be shielded from herbicide.
Prescribed Fire	CR	-may stimulate Bd coppice from seedlings, and encourage Or by controlling advance growth of competing Mh. Will not benefit Mh regeneration effort.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Bd (often sprout origin). Aw, Cb may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Not required for Mh or most other related species typical of this ecosite.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species typical of this ecosite.
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or seedling / sapling (esp. if cost or logistics prevent prescribed fire), otherwise normally not warranted until desired clear bole length is established.
Chemical	CR	-may be appropriate for release of Or seedling / sapling growth from competitors
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 26.2

Sugar Maple / Basswood on Fresh to Moist Soils

Summary of ecosite features: Mh and Bd have fairly equal overstory representation, with lesser quantities of trembling aspen, yellow birch, and black ash on the moister sites. Mh dominates understory, with minor representation of Ew, Aw, B, Iw, Bd. Because of water availability and generally finer textured soils, this ecosite has potential to produce high quality sawlogs.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	NR	
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-applicable if AGS levels in overstory insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1) or -in situations of higher Bd / By / Aw composition when regeneration to mid-tolerants is the principal objective. May stimulate Bd regeneration of seed origin.
SELECTION		
Single Tree	R	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Aw regeneration will develop as well to some extent but will require timely release if Aw component is an objective.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Bd, By, Aw or Cb) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-will not benefit Mh or Bd (or Aw) regeneration effort, but will assist in promoting By regeneration in canopy gaps by controlling advance growth of competing Mh and providing suitable seedbed conditions. Summer / fall logging may benefit By reproduction -sites very prone to compaction where <30% coarse fragments and fine-textured soils; some risk of erosion if continuous areas of mineral soil exposure occurs on slopes and when soils are coarse or silty, slope may limit choice and use of equipment.
Chemical	CR	-will not benefit Mh or Bd (or Aw) regeneration effort. May have application in By regeneration efforts (requires further testing).
Prescribed Fire	CR	-will not benefit Mh regeneration effort, but may encourage By by controlling advance growth of competing Mh. and enhancing seedbed conditions and Bd by stimulating coppice from seedlings. Operationally difficult to apply in Group Selection situations.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of Bd (often sprout origin). Aw may be present and may respond to release if not excessively suppressed to date.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	R	-approach may be utilized to enhance By regeneration following site preparation where By seed trees not present or seed crop not anticipated. Not required for Mh or most other related species.
Planting	NR	-not required
TENDING TREATMENTS		
Manual / Mechanical	CR	-may have application for release of Or or By seedling / sapling, otherwise normally not warranted until desired clear bole length is established
Chemical	NR	
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 27.1

Sugar Maple / White Birch / Poplar on Dry to Moderately Fresh Soils

Summary of ecosite features: Bw, Mh and Pw the dominant overstory species, with lesser representation of Pt, Pg, By, Bw, and Ce. High levels of hardwood and conifer regeneration, dominated by Mh, and lesser concentrations of Ms and B. Soils generally >60 cm. in depth, and coarse textured. Limited potential to produce high quality tolerant hardwood sawlog material on most sites. This ecosite occurs primarily in SR 5E. White pine likely the dominant pre-settlement cover type.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	CR	-appropriate if intent is to convert to conifer species, and commitment is made to required follow-up treatments, including SIP, plant, tending (refer to Silvicultural Guide for Conifer Forests in the Great Lakes / St. Lawrence Forest), or -intent is to manage for intolerant hardwoods of pulp quality
Seed-tree	CR	-appropriate if intent is to convert to Pw, and commitment is made to required follow-up treatments. Pw Seed-trees retained to provide a component of natural regeneration (refer to Silvicultural Guide for Conifer Forests in the Great Lakes / St. Lawrence Forest).
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	CR	-system of choice when regeneration to mid-tolerants (Pw, By, Sw) is the principal objective, or -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	CR	-system of choice on moderately fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration, and to manage for hardwood sawlog material. -most appropriate on sites with higher Mh composition.
Group	CR	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Or, Pw) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-appropriate only to the clearcut system.
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-required if conversion to Pw / Or, or enhancement of Bw regeneration is the objective -sites very prone to compaction where <30% coarse fragments and fine-textured soils; some risk of erosion if continuous areas of mineral soil exposure occurs on slopes and when soils are coarse or silty, slope may limit choice and use of equipment.
Chemical	R	-may be appropriate when intention is to manage for Or regeneration, or to convert to conifer.
Prescribed Fire	R	-pre-harvest burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance Pw or Or regeneration, preparing seedbed, reducing Mh and B advance growth. Light fires greatly reduce but may not eliminate Pw advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely. If intent is to manage for the mid-tolerant Pw or By, supplemental SIP and possibly planting (for Pw) will be required.
Natural - ingress	R	-will develop from residuals retained following selection, shelterwood and (to a lesser extent) clearcut with seed-tree management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	R	-may have application in regenerating By or Or on these sites, in the absence of a natural seed source, but not required in other circumstances.
Planting	CR	-if conversion to conifer is the objective.
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	R	-may be required if conversion to conifer is the objective, due to high levels of aggressive Mh regeneration advance growth.
Pre-commercial thinning	CR	-dependent on target species.

SILVICULTURAL OPTIONS FOR ECO-SITE 27.2

Sugar Maple / White Birch / Poplar on Fresh to Moist Soils

Summary of ecosite features: Sugar maple and white birch are the dominant overstory species, with lesser representation of Ms, Pt, Pw, Ce, By, Sw and B. Moderate to high levels of hardwood and conifer regeneration, dominated by B, Ms and Mh. Minor amounts of Or may be represented as well. Soils predominantly >60 cm. in depth. Both Mh and Bw will have potential to produce high quality sawlog material on some sites. This ecosite occurs throughout SR 5E, and occasionally in 4E.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	CR	-appropriate if intent is to convert to conifer species, and commitment is made to required follow-up treatments, including SIP, plant, tending (refer to Silvicultural Guide for Conifer Forests in the Great Lakes / St. Lawrence Forest), or -intent is to manage primarily for intolerant hardwoods.
Seed-tree	CR	-appropriate if intent is to convert to Pw, and commitment is made to required follow-up treatments. Pw Seed-trees are retained to provide a component of natural regeneration. Refer to Silvicultural Guide for Conifer Forests in the Great Lakes / St. Lawrence Forest.
Strip	NR	
SHELTERWOOD		
Uniform shelterwood	R	-system of choice when regeneration to mid-tolerants (Pw, By, Sw) is the principal objective, or -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	CR	-system of choice in stands with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration, minimizing intolerant hardwood component.
Group	CR	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Pw, Or) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-appropriate only to clearcut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-sites very prone to compaction where <30% coarse fragments and fine-textured soils; some risk of erosion if continuous areas of mineral soil exposure occurs on slopes and when soils are coarse or silty. -slope may limit choice and use of equipment.
Chemical	R	-may be appropriate when intention is to manage for Or regeneration, or to convert to conifer.
Prescribed Fire	CR	-pre-harvest burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance Pw or Or regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh, B, Ms seed origin advance growth likely, lesser quantities of Or and intolerants.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-procedures being tested for Or. Not required for Mh or most other related species.
Planting	CR	-procedures being tested for Or. Not required for Mh or most other related species.
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	NR	
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 28.1

Sugar Maple / Eastern Hemlock / Yellow Birch on Dry to Moderately Fresh Soils

Summary of ecosite features: Sugar maple and hemlock are the dominant overstory species, each averaging 35 to 40 per cent of stand basal area. Yellow birch averages approximately 12 per cent, with lesser representation of Ms, Be and Ce. The hemlock component may occur in concentrated patches on ridge tops, or as individuals scattered through the hardwood. Moderate to high levels of hardwood regeneration, dominated by Mh, B, Ms, He, and By. Soils are of variable depth. Quality sawlog production potential increases as moisture regime moves to moderately fresh condition. This ecosite occurs predominantly in the Algonquin Highlands.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	-mixture of age and size classes is typical. Application of this system will often result in unacceptable loss of AGS poles and small sawlogs.
Seed-tree	NR	
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-system of choice when regeneration to mid-tolerants is the principal objective, or -when managing concentrations of hemlock - (attention must be paid to different crown closure requirement) or -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	R	-system of choice on moderately fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh, Be) regeneration. Basal area targets may be modified to promote hemlock regeneration.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (By) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	R	-light scarification will provide sufficient site disturbance necessary to enhance By or He regeneration.
Chemical	CR	-not generally required when intention is to manage for Mh or By regeneration, may have application when encouraging He regeneration.
Prescribed Fire	R	-pre-harvest spring or fall burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance By regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, low quantities of He and By.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	R	-may have application in regenerating By on these sites, in the absence of a natural seed source or seed crop.
Planting	NR	
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	R	-if He is the objective, chemical release from developing hardwood competition may be required.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 28.2

Sugar Maple / Eastern Hemlock / Yellow Birch on Fresh to Moist Soils

Summary of ecosite features: Sugar maple and hemlock are the dominant overstory species, each averaging approximately 30 per cent of stand basal area. Yellow birch averages approximately 16 per cent, with lesser representation of Ms, Be and Pw. The hemlock component may occur in concentrated patches on ridge tops, or as individuals scattered through the hardwood. Soils are predominantly >60 cm. in depth. Both Mh and By will have potential to produce high quality sawlog material although the quality development potential of By exceeds that of Mh on the moist sites. This ecosite occurs throughout SR 5E, but is dominant in the Algonquin Highlands.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	-mixture of age and size classes is typical. Application of this system will often result in unacceptable loss of AGS poles and small sawlogs.
Seed-tree	NR	
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	R	-system of choice when regeneration to mid-tolerants is the principal objective, or -when managing concentrations of hemlock - (attention must be paid to different crown closure requirement) or -if AGS levels insufficient for selection management (<9 m^2/ha)
SELECTION		
Single Tree	R	-system of choice on fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh, Be) regeneration. Basal area targets may be modified to promote hemlock regeneration.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (By) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	R	-light scarification will provide sufficient site disturbance necessary to enhance By or He regeneration.
Chemical	CR	-not generally required when intention is to manage for Mh or By regeneration, may have application when encouraging He regeneration.
Prescribed Fire	R	-pre-harvest spring or fall burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance By regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, low quantities of By.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating By on these sites, in the absence of a natural seed source.
Planting	NR	
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	CR	-if He is the objective, chemical release from developing hardwood competition may be required.
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 29.1

Sugar Maple / Yellow Birch on Dry to Moderately Fresh Soils

Summary of ecosite features: Sugar maple and yellow birch the dominant overstory species, with lesser representation of Ce, Mr, Sw, Bw, and B. Moderate levels of hardwood and conifer regeneration, dominated by Mh and B. Soils generally >60 cm. in depth, coarse sandy to coarse loamy. On many sites, both Mh and By will have potential to produce high quality sawlog material although the quality development potential of By may exceed that of Mh. This ecosite occurs throughout SR 4E.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	CR	-if By regeneration is the objective - must accept reduced expectation for stocking and future yield, will be ineffective unless follow-up site preparation is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	R	-system of choice when regeneration to mid-tolerants is the principal objective. -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	R	-system of choice on moderately fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration. Most effective on moderately fresh sites.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (By, Sw) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	R	-light scarification will provide sufficient site disturbance to enhance By regeneration.
Chemical	CR	-not required when intention is to manage for Mh regeneration -if necessary to control competing hardwood trees and shrubs in understory prior to By establishment. Seedbed prep will be required as well. Avoid areas of advanced By
Prescribed Fire	R	-pre-harvest spring or fall burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance By regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of By.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	R	-may have application in regenerating By on these sites, in the absence of a natural seed source.
Planting	NR	
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	CR	-selective methods to remove individual stems competing with By
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 29.2

Sugar Maple / Yellow Birch on Fresh to Moist Soils

Summary of ecosite features: Sugar maple and yellow birch are the dominant overstory species, with lesser representation of Ce, B, Pt, Sw, Ms, and Bw. Moderate levels of hardwood and conifer regeneration, dominated by Mh and B, but minor amounts of By and Ms represented. Soils predominantly >60 cm. in depth, finer textured than 29.1. Both Mh and By will have potential to produce high quality sawlog material although the quality development potential of By may exceed that of Mh. This ecosite occurs throughout SR 4E.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality. High quality sawlog and veneer production is normally the priority.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	
Seed-tree	CR	-if By regeneration is the objective - must accept reduced expectation for stocking and future yield. Approach will be ineffective unless follow-up site preparation is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	R	-system of choice when regeneration to mid-tolerants such as By is the principal objective, or -if AGS levels insufficient for selection management (<9 m^2/ha, or as defined in Section 9.3.1)
SELECTION		
Single Tree	R	-system of choice on. fresh sites with >9 m^2/ha AGS, and objective to produce predominantly tolerant hardwood (Mh) regeneration.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (By) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	NR	-unacceptable stem damage to residuals will result if applied in a partial cut system
Forest Renewal		
Site Preparation		
Mechanical	R	-light scarification will provide sufficient site disturbance to enhance By regeneration.
Chemical	CR	-not required when intention is to manage for Mh regeneration -if necessary to control competing hardwood trees and shrubs in understory prior to By establishment. Seedbed prep will be required as well. Avoid areas of advanced By.
Prescribed Fire	R	-pre-harvest spring or fall burns combined with scarification during the harvesting process will provide sufficient site disturbance to enhance By regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of By.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	R	-may have application in regenerating By on these sites, in the absence of a natural seed source.
Planting	NR	
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	CR	-selective methods to remove individual stems competing with By
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ECO-SITE 35
Lowland Hardwoods on Very Moist to Fresh Soils

Summary of ecosite features: Ab, Pt, and Mh are the dominant overstory species, with By, Ms, Sw, Pw, Bd and Pb as lesser associates. Ab and B are the dominant regeneration species with lesser representation of Mh and Ew. Soils are generally >60 cm. in depth and fine textured promoting high levels of tall hardwood shrubs. Quality development potential is good for By and Pw on fresh to moist sites, but Mh quality declines because of the species' relatively low tolerance for poorly drained sites.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	CR	-appropriate when objective is to increase intolerant hardwood component.
Seed-tree	CR	-basic level silvicultural approach promoting some additional Pw in regenerated stand.
Strip	CR	-basic level silvicultural approach promoting some additional Pw in regenerated stand.
SHELTERWOOD		
Uniform shelterwood	R	-system of choice if regeneration of the stand to a high proportion of mid-tolerants (Ab, By, Ms, Sw, Pw) is the objective, understanding that follow-up treatments will very likely be required.
SELECTION		
Single Tree	CR	-appropriate where management objective is to encourage Ms.
Group	R	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (Ab, By, Pw, Aw) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-site disturbance will enhance regeneration opportunities for By, Sw, Pw. -fine textured soils with <30% coarse fragments are common in this ecosite, and are prone to compaction when wet.
Chemical	R	-may be required alone or as supplement to mechanical SIP due to competition prone nature of this ecosite.
Prescribed Fire	R	-may enhance By regeneration, but due to slope position and resultant moisture levels, may be difficult to implement.
Regeneration		
Natural - advance growth	CR	-if Ab and B are desired
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory and post-harvest treatment will enhance chances of mid-tolerant representation as regeneration.
Seeding	R	-may have role in regenerating By on these sites, in the absence of a natural seed source.
Planting	R	
TENDING TREATMENTS		
Manual / Mechanical	NR	-not warranted until desired clear bole length is established
Chemical	CR	-may be appropriate for release of conifer seedling / sapling growth from competitors, but desired species must be protected.
Pre-commercial thinning	R	-appropriate on most productive sites, with species which will respond to release (i.e. By, Sw, Pw)

SILVICULTURAL OPTIONS FOR ST 15 (Northeast)

Tolerant Hardwood Mixedwood on Fresh, Coarse Loamy to Silty Soils

Summary of ecosite features: This ecosite is made up of mixedwood stands with a red maple component, as well as Bw, Pt, Sw, B, Sb and By. Most species, except for By, are represented in the regeneration. High coarse fragment levels on shallow till are typical.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	-will provide competitive advantage to intolerant hardwood, and release advance growth B. Red maple will regenerate from seed and stump sprout origin, but unless stocking is high, will have poor form and quality. By will decline as a stand component. -an option when intent is to convert to conifer species through subsequent SIP and artificial regeneration program.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-when regeneration to mid-tolerants is the principal objective. If required follow-up (SIP / tending) assured, will provide opportunity for natural regeneration of Sw.
SELECTION		
Single Tree	NR	
Group	NR	
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance Sw regeneration, or By regeneration in a good By seed year.
Chemical	CR	-not required when intention is to manage for By regeneration. May be appropriate if management objective is to convert to a conifer cover type.
Prescribed Fire	CR	-if converting to conifer.
Regeneration		
Natural - advance growth	R	
Natural - ingress	R	-will develop from residuals retained following shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating some species
Planting	CR	-if management objective is to convert to conifer cover type.
TENDING TREATMENTS		
Manual / Mechanical	R	-may be appropriate if management objective is to convert to a conifer cover type
Chemical	R	-may be appropriate if management objective is to convert to a conifer cover type
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ST 16 (Northeast)
Sugar Maple / Yellow Birch on Fresh Sandy to Silty Soils

Summary of ecosite features: Sugar maple and yellow birch are the dominant overstory species, normally making up at least 50 per cent of stand basal area. Pt, Bw and Sw are often represented as lesser stand components. Low to moderate levels of hardwood and conifer regeneration, including B, Sw, Mh, By and Pt. Quality development potential of By exceeds that of Mh due to occurrence of site type at the northern extent of the Mh range.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	NR	-approach will result in much higher representation of intolerant hardwood and balsam fir with lesser component of low quality Mh.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	R	-system of choice when regeneration to mid-tolerants such as By is the principal objective. Reduced expectation for stocking and future growth unless follow-up site preparation is assured.
SELECTION		
Single Tree	CR	-applicable on sites capable of producing high quality Mh. Condition indicated by soil condition and presence of >9 m^2/ha AGS. Objective to produce predominantly tolerant hardwood (Mh) regeneration.
Group	CR	-system of choice where objective is to manage for high quality tolerant hardwood, maintaining a component of mid-tolerants (By) in the stand.
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system, may have application in clearcut situations.
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance By regeneration in a good By seed year. Heavy site preparation required if management objective is to convert to a conifer cover type.
Chemical	CR	-not required when intention is to manage for Mh or By regeneration. May be appropriate if management objective is to convert to a conifer cover type.
Prescribed Fire	CR	-pre-harvest fall burns combined with scarification during the harvesting process will provide site disturbance necessary to enhance By regeneration, preparing seedbed, reducing Mh and B advance growth.
Regeneration		
Natural - advance growth	R	-high levels of Mh seed origin advance growth likely, lesser quantities of By.
Natural - ingress	R	-will develop from residuals retained following selection and shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating By on these sites, in the absence of a natural seed source.
Planting	CR	-if management objective is to convert to conifer cover type
TENDING TREATMENTS		
Manual / Mechanical	CR	-in Mh / By management programs, not warranted until desired clear bole length is established. -may be appropriate if management objective is to convert to a conifer cover type
Chemical	CR	-in Mh / By management programs, not warranted. -may be appropriate if management objective is to convert to a conifer cover type
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ES 19 (Northwest)
Hardwood - Fir - Spruce Mixedwood: Fresh, Sandy - Loamy Soil

Summary of ecosite features: Dominated by trembling aspen, white birch and balsam fir, with occasional occurrences of white and black spruce. May include some yellow birch, red maple and sugar maple in Site Regions 4S, 4W, and 5S.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	-will provide competitive advantage to intolerant hardwood, and release advance growth B. Red maple will regenerate from seed and stump sprout origin, but unless stocking is high, will have poor form and quality. By, if present, will decline as a stand component. -normal approach if option to manage for conifer species through subsequent SIP and, if required, artificial regeneration program.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield, increased intolerant hardwood competition. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-when regeneration to mid-tolerants is the principal objective. If required follow-up (SIP / tending) assured, will provide opportunity for natural regeneration of Sw, Mr.
SELECTION		
Single Tree	NR	
Group	NR	
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance By regeneration, or to enhance opportunities for conifer regeneration. Shallow (20-100 cm) sands over bedrock are common, in which case light mech. SIP is desirable.
Chemical	CR	-not required when intention is to manage for By regeneration. May be appropriate if management objective is to manage for a conifer cover type.
Prescribed Fire	CR	-if managing for conifer or By.
Regeneration		
Natural - advance growth	R	
Natural - ingress	R	-will develop from residuals retained following shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating some species, including By, if site lacks sufficient seed producers
Planting	CR	-if management objective is to convert to conifer cover type.
TENDING TREATMENTS		
Manual / Mechanical	R	-may be appropriate if conifer is the management objective
Chemical	R	-may be appropriate if conifer is the management objective
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ES 21 (Northwest)
Fir - Spruce Mixedwood: Fresh, Coarse Loamy Soil

Summary of ecosite features: Dominated by balsam fir, white spruce and black spruce with mixtures of trembling aspen and white birch. May include some yellow birch and sugar maple in Site Regions 4S, 4W, and 5S.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	-will provide competitive advantage to intolerant hardwood, and release advance growth B. Red maple will regenerate from seed and stump sprout origin, but unless stocking is high, will have poor form and quality. By, if present, will decline as a stand component. -normal approach if option to manage for conifer species through subsequent SIP and, if required, artificial regeneration program.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield, increased intolerant hardwood competition. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-when regeneration to mid-tolerants is the principal objective. If required follow-up (SIP / tending) assured, will provide opportunity for natural regeneration of Sw, Mr.
SELECTION		
Single Tree	NR	
Group	NR	
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance By regeneration, or to enhance opportunities for conifer regeneration. Varied topographic relief may reduce mechanical SIP coverage.
Chemical	CR	-not required when intention is to manage for By regeneration. May be appropriate if management objective is to manage for a conifer cover type.
Prescribed Fire	CR	-if managing for conifer or By.
Regeneration		
Natural - advance growth	R	
Natural - ingress	R	-will develop from residuals retained following shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating some species, including By, if site lacks sufficient seed producers
Planting	CR	-if management objective is to convert to conifer cover type.
TENDING TREATMENTS		
Manual / Mechanical	R	-may be appropriate if conifer is the management objective
Chemical	R	-may be appropriate if conifer is the management objective
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ES 23 (Northwest)

Hardwood - Fir - Spruce Mixedwood: Moist, Sandy - Coarse Loamy Soil

Summary of ecosite features: Dominated by trembling aspen, white birch, balsam fir and occasional occurrence of white spruce, black spruce and jack pine. Deciduous trees comprise more than 50 per cent of the canopy. Yellow birch and red maple may occur in Site Regions 4S, 4W, and 5S.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	-will provide competitive advantage to intolerant hardwood, and release advance growth B. Red maple will regenerate from seed and stump sprout origin, but unless stocking is high, will have poor form and quality. By will decline as a stand component. -an option when intent is to convert to conifer species through subsequent SIP and artificial regeneration program.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield, increased intolerant hardwood competition. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-method of choice when regeneration to mid-tolerants is the principal objective. If required follow-up (SIP / tending) assured, will provide opportunity for natural regeneration of Sw, Mr.
SELECTION		
Single Tree	NR	
Group	NR	
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance By regeneration, or to convert to conifer.
Chemical	CR	-not required when intention is to manage for By regeneration. May be appropriate if management objective is to convert to a conifer cover type.
Prescribed Fire	CR	-if converting to conifer, or managing for By.
Regeneration		
Natural - advance growth	R	
Natural - ingress	R	-will develop from residuals retained following shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating some species, including By, if site lacks sufficient seed producers
Planting	CR	-if management objective is to convert to conifer cover type.
TENDING TREATMENTS		
Manual / Mechanical	R	-may be appropriate if management objective is to convert to a conifer cover type
Chemical	R	-may be appropriate if management objective is to convert to a conifer cover type
Pre-commercial thinning	R	

SILVICULTURAL OPTIONS FOR ES 29 (Northwest)

Hardwood - Fir - Spruce Mixedwood: Fresh, Fine Loamy - Clayey Soil

Summary of ecosite features: Dominated by trembling aspen and occasionally white birch, with a conifer mix of balsam fir, white spruce, black spruce and occasionally jack pine. Deciduous trees comprise more than 50 per cent of the canopy. Yellow birch, red maple, and large-toothed aspen may occur in Site Regions 4S, 4W, and 5S.

Silvicultural Objective: Range of species and product possibilities depending on moisture regime, soil texture and depth, existing quality.

Silviculture System • Harvest Method		**Comments**
CLEARCUT		
Conventional	R	-will provide competitive advantage to intolerant hardwood, and release advance growth B. Red maple will regenerate from seed and stump sprout origin, but unless stocking is high, will have poor form and quality. By will decline as a stand component. -an option when intent is to convert to conifer species through subsequent SIP and artificial regeneration program.
Seed-tree	CR	-if By regeneration is the objective - implementation of this approach assumes reduced expectation for stocking and future yield, increased intolerant hardwood competition. Approach will be ineffective unless follow-up site preparation is assured.
Strip	CR	-if By regeneration is the objective - will be ineffective unless follow-up site preparation timed to a seed year is assured. Assumes inadequate stocking to successfully implement uniform shelterwood system.
SHELTERWOOD		
Uniform shelterwood	CR	-method of choice when regeneration to mid-tolerants is the principal objective. If required follow-up (SIP / tending) assured, will provide opportunity for natural regeneration of Sw, Mr.
SELECTION		
Single Tree	NR	
Group	NR	
LOGGING METHOD		
Log Length	R	-careful felling and skidding practices mandatory.
Tree Length	R	-careful felling and skidding practices mandatory.
Full Tree	CR	-unacceptable stem damage to residuals will result if applied in a partial cut system
RENEWAL TREATMENTS		
Site Preparation		
Mechanical	CR	-light scarification will provide site disturbance necessary to enhance By / Sw regeneration, or to convert to conifer. Compaction / rutting / puddling and / or erosion potential on finer textured sites in wet weather.
Chemical	CR	-not required when intention is to manage for By regeneration. May be appropriate if management objective is to convert to a conifer cover type.
Prescribed Fire	CR	-if converting to conifer.
Regeneration		
Natural - advance growth	R	
Natural - ingress	R	-will develop from residuals retained following shelterwood management. -representation as regeneration primarily dependent on light and seedbed requirements of the individual species, and availability of seed source. Increased representation in the overstory will enhance chances of representation as regeneration.
Seeding	CR	-may have application in regenerating some species, including By, if site lacks sufficient seed producers
Planting	CR	-if management objective is to convert to conifer cover type.
TENDING TREATMENTS		
Manual / Mechanical	R	-may be appropriate if management objective is to convert to a conifer cover type
Chemical	R	-may be appropriate if management objective is to convert to a conifer cover type
Pre-commercial thinning	R	

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 species	
Armillaria "complex"	*Armillaria ostoyae* (Romagn.) Herink	
shoestring root rot		
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.	