

Introduction to Forestry

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Chapter 1

ONTARIO FORESTRY PAST AND PRESENT

Peter Williams

THE GROWTH OF ONTARIO FORESTRY

Forestry has long been a vital industry in Canada, and in the 1800's it was one of the principal factors dictating the settlement of Quebec, Ontario and British Columbia. Forests were first cleared around Quebec City in the 17th century and then clearing spread up the St. Lawrence river to the richer and more fertile land surrounding Lake Ontario and Lake Erie. In many areas of Eastern Canada, forests were cleared for agriculture and pioneer settlements (Fig. 1.1). In more rugged areas the forests were indiscriminately cut for timber and other wood products.

The potential of Canadian lumber to both French and British colonial powers was beginning to be realized in the early 1800's. The biggest and best Canadian white pines were

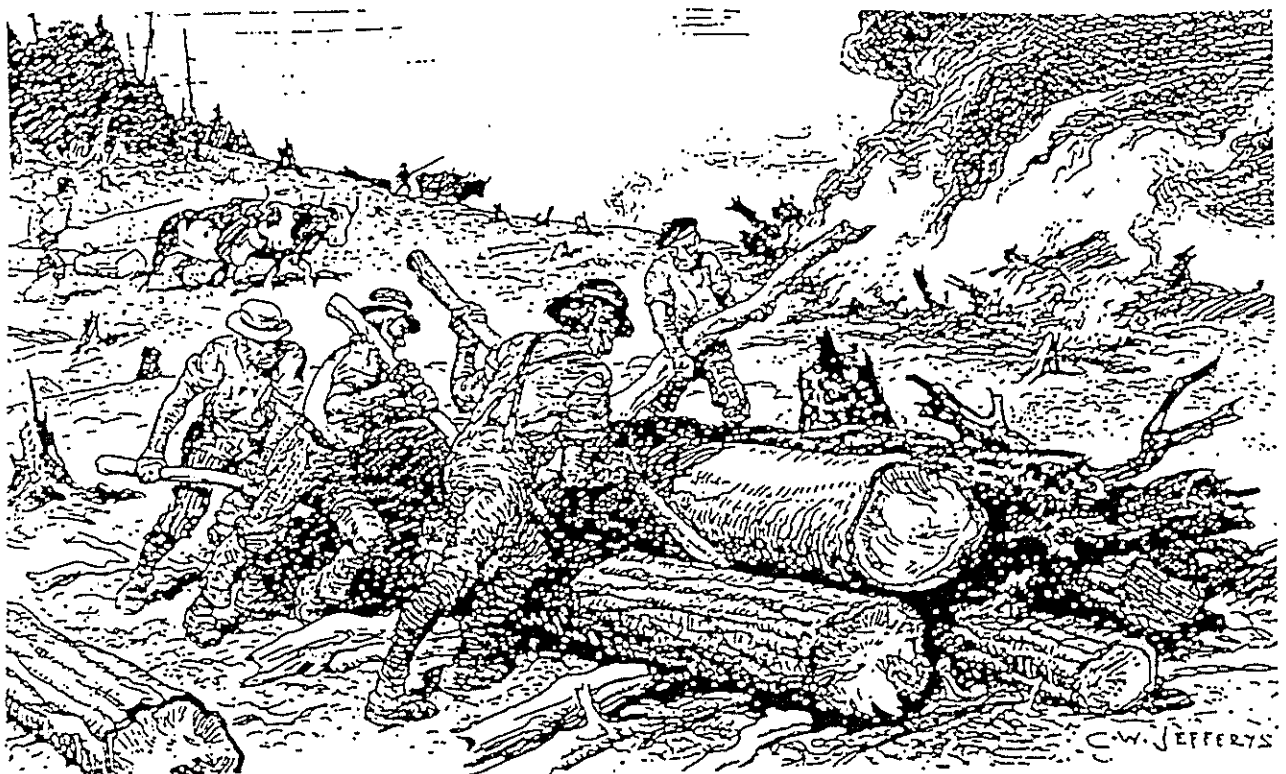


Figure 1.1 Clearing the forests for settlement (courtesy of the public archives of Canada C73549)

harvested and shipped to France and later Britain to maintain and build their naval fleets. Canada became Britain's main source of timber when timber supplies were cut off from the Baltics during the Napoleonic wars. In the Ottawa Valley the pines were squared and then transported downstream in rafts to Quebec City for shipment to Britain. Once the best timber was cut, the stands were cut for "waney timber". This timber had round corners because it was too small to make square. Beginning around 1850, declining European exports and new markets in the U.S. for sawn timber spurred the development of a domestic sawmilling industry, which grew to utilize this "lower quality" timber.

Railways opened up much of the rest of Ontario and the pine logging continued until the resource was depleted through land clearing and logging. By 1900, timber supplies in southern Ontario were depleted. Railways to the north created a new supply of timber for milling, and pulp and paper. By the end of the century the first attempts were made to encourage reforestation. The Reforestation Act was passed in 1921 to try to combat the problem of exploited and deforested land by allowing the formation of Agreement Forests. Table 1.1 summarizes forestry history in Ontario.

Table 1.1: Summary of Ontario forest and settlement history

12,000-8000 B.C.	Retreat of glaciers.
Pre-1700	North American natives, relatively passive forest users; used fire to manage vegetation for wildlife; hunting.
1763	Broad Arrow policy - white pine were marked with an arrow and reserved for masts for the British Navy; lasted until the advent of steam ships (late 1800's).
1700-1800 <i>circa.</i>	Europeans begin settling Quebec/Ontario; mostly trapping and setting up small farms.
1800 <i>circa.</i>	British timber supplies in Baltic cut off by Napoleonic wars.
1800-1850 <i>circa.</i>	Lobbying by British timber importers got reduced tariff for imported timber. Raw materials (logs or sawn timbers) could be imported to Britain tax-free.
1806	First raft of square-timbers down the Ottawa River. Only perfect logs were taken, those with minor flaws were left in the woods.
1850 <i>circa.</i>	Preferential tariff for timbers removed by Britain. New markets opened up for sawn lumber in U.S.
1870-1900 <i>circa.</i>	Railways opened up Central Ontario over to Midland. First legislative attempts to encourage tree planting.

1871	The first act was passed to encourage tree planting along roads. 1200 sawmills in the Ottawa area alone cutting 250 million board feet/year.
1886-1887	The experimental farm in Ottawa was established.
1900 <i>circa.</i>	Forestry in Ontario became dominated by the pulp and paper industry. Timber supplies depleted in south and the north was opened up.
1905	First government tree nursery was established at Guelph, and was later moved to St. Williams to become the first forest station.
1907	Faculty of Forestry, originally started at Guelph, established at Toronto.
1921	The Reforestation Act; allowed for the development of Agreement Forests, largely in southern Ontario.
1927	The Forestry Act replaced former; changed reforestation purposes to forestry purposes.
1935 <i>circa.</i>	Make work projects during the depression provided for the planting of roadside trees, windbreaks, and reforestation of degraded agriculture land.
1946	The Conservation Authorities Act allowed for the formation of CA's to deal with erosion and flooding problems.
1946-1957	Complete inventory of Ontario forests.
1950	Forest management units created. Actual harvest of timber brought into line with volume produced on land, as indicated by this new survey. Consolidation of the Tree Planting Act (1914), Trees Conservation Act (1946) and Municipal Reforestation Act (1950) allowed municipalities to pass regulations controlling tree-cutting practices, permit townships and counties to institute reforestation programs. Department of Lands and Forests policy allowed for extension services to private landowner.
1955-1985 <i>circa.</i>	Tremendous backlog of lands not sufficiently regenerated (NSR) to desirable species (spruce, fir, pine) resulted from cutting without strict adherence to proper silvicultural practices. Low value species such as aspen or birch regenerated nicely in many cases.
1960	Forest Resource Inventory (FRI), based on aerial photography, is used to regulate harvest operations.

Introduction

- 1966 Woodlands Improvement Act allowed the Department of Lands and Forests to enter into agreements to subsidize forest management on private lands. Usually involves tree planting, but also covers natural woodlot management.
- 1970 "Forestry purposes" redefined in the Forestry Act to give equal standing to all elements (wood production, wildlife, flood protection, recreation, etc.).
- 1979 Forest Management Agreements (FMA's) created. Agreements between companies and crown which give companies tenure to the land. Companies are responsible for regeneration/silviculture.
- 1990- Still have a backlog of NSR areas
- FMA's going strong, but are having problems with some agreements.
- Environment Assessment (EA) of management practices on Crown lands will likely result in significant changes in practices, but more importantly attitudes and policies of OMNR, companies and other parties.
- 1993 Private forest land tax rebate no longer available.
- 1994 Environmental assessment of Ontario's forest management practices completed, with some new recommendations to improve management.
-

The struggle for prudent stewardship of forested land continues. This is largely due to the recognition of the importance of forestry to the Canadian economy, to the realization that forests are being depleted, and to heightened public awareness of environmental issues. In 1989, the industry employed 888,000 people directly or indirectly, which translates to 1 of every 14 jobs. In 1988, 1 million ha of forested land were harvested in Canada, which produced \$49 billion worth of forest products sold domestically and exported (Table 1.2). In that same year 823,000 ha were regenerated. Good management of remaining forest stands and regenerated stands is necessary if harvesting is to continue at this rate.

Table 1.2 Summary of Canadian forestry statistics (Forestry Canada, 1991).

<u>FOREST RESOURCES</u>	<u>Million ha</u>	<u>TRADE (1989)</u>
Total area	997	Value of exports \$22.8 billion
Forest land	453	17% of all Canadian exports
Productive forest land	244	21% of world trade in forest products
Area regenerated (1988)	.823	Major value of products exported
Area harvested (1988)	1	wood pulp 30%, newsprint 25%, softwood lumber 24%
Insect defoliation (1989)	19	Major export markets
Area burned (1989)	7.3	U.S. 65%, EEC 15%, Japan 11%

OWNERSHIP OF PRODUCTIVE FOREST LAND		INDUSTRY PROFILE
Provincial	80%	Total value of shipments (1988) \$49 billion
Federal	11%	54% sold domestically, 46% exported
Private	9%	Number of establishments (1988) 14,944
430 000 woodlot owners		logging 10,587, wood industry 3,639, paper 718
		Employment (1989) 888,000 jobs
		Direct jobs 348,000
		Indirect jobs 540,000
		Forest Dependent Communities 348

IMPORTANCE OF FORESTS AND FORESTRY TO ONTARIO

With respect to the value of Canadian exports of forest products, Ontario (\$3.9 billion) is ranked third behind British Columbia (\$10 billion) and Quebec (\$5.1 billion) (Table 1.3). Ontario has 38.3 million ha of productive forest, mostly in Northern Ontario. The annual volume of wood harvested on Crown lands is 19-20 million m³, generating over \$60 million in direct revenue to the crown and providing 84,000 direct and 85,000 indirect jobs.

Table 1.3 Summary of forestry statistics for the 4 major timber producing provinces (Forestry Canada, 1991).

	ONT.	B.C.	QU.	N.B.	N.W.T.
OWNERSHIP OF PRODUCTIVE FOREST					
Provincial	84%	95%	87.5%	49%	
Federal	1%	1%	.5%	2%	100%
Private	15%	4%	12%	49%	
FOREST RESOURCE					
Total area (10 ⁶ ha)	107	95	154	7	343
Forest Land (10 ⁶ ha)	81	60	94	6	61
Productive forest land (10 ⁶ ha)	38	51	55	6	14
Reserved forest land (10 ³ ha)	1,700	2,400	378	32	1100
Area regenerated (10 ³ ha)	181	209	256	62	.2
Area Harvested (10 ³ ha)	237	244	315	87	.4
Defoliated by insects (10 ³ ha)	14,500	299	1,100	398	99
Burned (10 ³ ha)	404	25	2,100	343	578
VALUE OF EXPORTS (billion \$)	4	10	5	1.5	*
EMPLOYMENT (10³ jobs)	169	194	210	30	*

* Not Available

FOREST REGIONS OF ONTARIO

There are four main forest regions in Ontario (Fig. 1.2). The boreal forest region of northern Ontario is the most productive in terms of the value to Ontario's economy. This is because of its size and because its predominant species, black spruce, is the most important species in the production of pulp and paper. Pulp and paper products (including newsprint, wood pulp and other paper and paperboard) make up 82% of Ontario's total forestry exports (Forestry Canada, 1991).

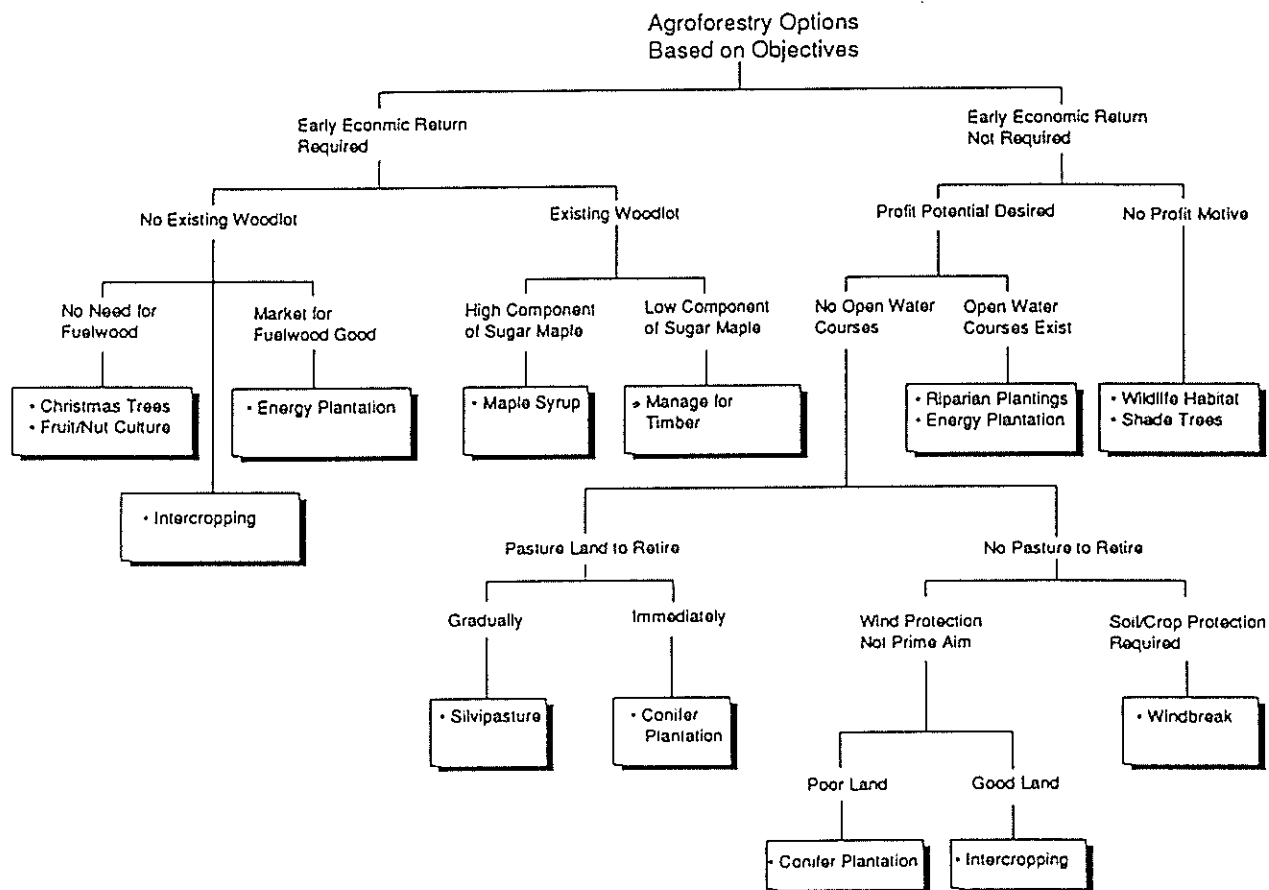
Recently interest has grown regarding the potential of the deciduous forests in southern Ontario. Southern Ontario is the most heavily populated region in Canada, but also one of the few regions able to grow valuable hardwood species profitably. The majority of woodlots in this area are privately owned. The importance of these woodlots cannot be overlooked, as income from forest products is substantial. For example, maple products alone generated over 7 million dollars in revenue in 1990. Short term monetary benefits of farm woodlots include the production of timber, fuel, fence posts, maple syrup and Christmas trees. There are also many indirect and long term benefits of properly managed, privately owned woodlots. Agroforestry (Chapter 13) also has the potential to play a role in both land stewardship and production.

-  **Boreal barrens:**
 - predominantly small black spruce, white spruce, tamarack and poplar
 - weather is too cold and soils are not fertile enough to produce economically valuable species
-  **Boreal forest:**
 - black spruce is the most predominant and economically valuable tree species
 - white spruce, jack pine white birch, balsam fir and poplar also predominate
-  **Great Lakes- St. Lawrence:**
 - typically mixed forest of white pine, spruce, red pine, sugar maple, white birch, red oak and yellow birch
-  **Deciduous: (Carolinian)**
 - sugar maple, beech, basswood, oak, walnut and hickory
 - noted for small populations of Carolinian trees such as sassafras, Kentucky coffee tree, black gum, and tulip tree
 - has mostly been cleared for agriculture and development



Figure 1.2 Forest Regions of Ontario.

Historically forests throughout the world have been used to exhaustion and replaced, often with agriculture. For example, Greece and Syria were once known for their trees. Lebanon too had vast cedar forests from which the navies of Persia, Phoenicia and Macedonia took their ship timber. Oak and beech forests dominated the landscapes of England and Ireland. Southern Ontario has been no exception. Recognizing that forests are vital to both the environment and the economy it seems prudent to look for land uses with a tree component. Agroforestry is developing where agriculture and forestry meet in a holistic approach to incorporating trees on farms. Trees are not a panacea, but they are a feasible land use option, and comprise a large component of several profitable land use alternatives (Fig. 1.3).



Trees play many ecological and economic roles.

1. Shelter/shade for soils, crops, buildings, streams and livestock can be provided through the use of windbreaks and bufferstrips.
2. Site Rehabilitation: trees assist soil amelioration, act as nutrient/ sediment filter, stabilize soil and help maintain the hydrological cycle.
3. Aesthetics: trees act as a visual/audio screen; enhance property value, and provide recreational opportunities and sites
4. Trees act as a carbon dioxide sink for green house gases associated with ozone depletion and global warming

5. Trees can provide wildlife habitat: food and shelter
6. Trees also produce: timber; fuelwood; maple syrup products; poles; Christmas trees; nectar for honey; nuts; fruit; pulp and paper; and hundreds of by-products such as turpentine, glue, perfume and rayon.

WOODLOT ECOLOGY

Forests consist of many organisms. Although trees are the most obvious, there are many other plant, animal and insect species that spend all or part of their lives in the forest. Many birds migrate south but return north to spend all of their time in the forest (e.g., ovenbirds, woodpeckers), while others may use the forest occasionally (e.g., red tailed hawks, great blue herons). Similarly, some mammals spend most of their time in the forest (e.g., squirrels, porcupines), while others use a variety of habitats including the forest (e.g., raccoons, deer).

Diversity also exists in the plant communities of the woodlot. Some plant species are adapted to life in dense forest while others are found in more open areas or in forests where trees have been removed. A vast variety of insects are found on the forest floor or associated with certain plants or animals. Some are beneficial to the farm woodlot or plantation (e.g., pollinators such as bees), while others are detrimental (e.g., defoliators such as the gypsy moth). Each species, plant, animal or insect interacts with all others, and plays an integral role in the forest ecosystem.

All management activities, from no management to intensive management, have effects on the forest community. Regardless of the type of management, some species will be favoured and others stressed. If a woodlot is heavily cut for fuelwood, often the defective and dead trees are removed. This leaves less shelter for cavity nesting birds and mammals, and less food for birds and mammals that rely on the insects and other organisms found in decaying trees. It also opens up the bush to the benefit of the remaining trees and animal species that rely on dense undergrowth. For example, since red oak is a valuable tree it is often harvested first by loggers with negative effects on wildlife that depend on acorns for food. Maple syrup production requires maple trees, so management of a woodlot for syrup tends to reduce species diversity as trees other than sugar maple tend to be removed. This results in forests that are very productive economically, but less suitable for some species of wildlife and more susceptible to disease or health problems. *The value of all species in the forest ecosystem should be considered when managing a woodlot.* This can often be accomplished without reducing the output of forest products.

Leaving a few dead trees in a stand may provide habitat for a variety of species including woodpeckers or other cavity nesters, while not affecting the potential fuelwood supply, especially if the snags are well rotted or are species that are not particularly good for firewood (e.g., poplar, basswood or hemlock). However, one must also consider the liability and risk associated with dead trees. A snag left along a well travelled path could result in an expensive law suit if it drops a branch on someone. Once again, the value of *all* species in the forest should be considered when managing a woodlot: this includes those passing through. Brush piles serve as shelter for small mammals such as rabbits, chipmunks, squirrels, weasels, and mice. The

Ministry of Natural Resources, Conservation Authorities, and local environmental groups offer several ways of improving habitat for selected species. For example, lists of tree and shrub species preferred by wildlife are available, along with plans for bird houses, duck boxes and bird feeders.

INTEGRATED RESOURCES MANAGEMENT (IRM)

Actively managing for many resources from the same woodlot is called **integrated resource management (IRM)**. IRM is a relatively recent term in forest management that represents a more holistic approach to resource management than previous philosophies.

The concept of **sustained yield** was one of the earliest philosophies of forest management used in North America and was based on European practices where the annual harvest of wood is equivalent to **net growth**. This concept allows forests to be managed to yield a continuous supply of wood products rather than to be overharvested, resulting in the depletion of the resource. The concept of sustained yield recognized only the value of wood products and was replaced in the 1960's by the concept of **multiple use**. Multiple use suggested that forests should be managed for many uses and allocated those uses to particular forest areas. Forests were divided up with particular areas managed for a primary use like timber, wildlife, wilderness of recreation. While multiple use acknowledged the importance of forest uses other than wood products, it did not adequately recognize that a forest or woodlot could provide multiple benefits from the same area. Although it acknowledged that a tract provided more than one use (e.g., deer use clearcuts), secondary objectives were not necessarily considered in management plans.

The philosophy of integrated resource management succeeded multiple use and was important in the development of the idea of using or considering the various roles and functions of forests. IRM and multiple use differ in that where multiple use divides up the forest by dominant land use, IRM strives to actively manage a forested area for many resources at one time. For example, the active management of forests can integrate wood production, wildlife management, recreation, watershed protection and biodiversity maintenance in each tract of forest. Managed woodlots in southern Ontario are probably the best examples of IRM since they are close to people; are relied upon for wood products regularly or occasionally; used for hiking, hunting and viewing nature; and serve as important havens for wildlife and woodland plants.

MANAGING THE WOODLOT

Whatever its purpose, managing a woodlot properly will limit stress on the trees and provide conditions for good tree health and growth. With that in mind, some important objectives of good woodlot management are noted as follows:

1. To provide sufficient high-quality growing stock and to keep the trees healthy and productive in order to maximize financial returns.

Introduction

2. To maintain the health and vigour of the forest and prevent the harvesting of crop trees before they reach their most useful and valuable size.
3. To minimize damage to soil, young growth and uncut trees during harvesting operations.
4. To protect the woodlot from fire, grazing and other damage.
5. To enhance wildlife habitat and tree species diversity.
6. To provide for soil and water conservation, aesthetic, and recreational requirements consistent with the landowner's personal objectives.

Once the management objectives for the woodlot are determined (recreation, aesthetics, hunting, wildlife, maple syrup, timber, or some combination) a management plan must be formed that will allow the forest to develop and maintain the desired characteristics. Such management plans usually consist of a series of timely plantings and/or cuts, along with plans for features like developing/restricting road access, altering wet areas (e.g. creating a pond, or removing a beaver dam) and fencing. These decisions will be based on the following:

1. Management objectives.
2. Stand history - How the forest has been managed in the past will have a large effect on current stand conditions, and what needs to be done in the future. For example, a stand that has been grazed will have little understorey.
3. Inventory - What is present in terms of species type, tree density, age, basal area, height, diameter, health, and stand structure will restrict management plans, at least in the short term. For example, it is unlikely one would decide to manage a 30-year-old pine plantation for maple production.
4. Site Conditions - Topography, soil texture, climate, and moisture and nutrient regime all affect what species will grow, how well they will grow, and how the stand would respond to various silvicultural techniques. For example, trees on an exposed site with shallow soil and a high water table are more subject to windthrow than a sheltered stand on deeper soil.
5. Site potential - What the site is capable of producing. For example, a site currently producing ironwood and low quality sugar maple may be better used to grow red oak.
6. Current and projected market value of potential products. This includes considering potential damage to the residual stand compared to the value of the wood products at the time of removal.
7. Operational characteristics - Size of the stand, location of the stand, availability of equipment, access to the stand, and condition of road access all affect stand management operations.

The management plan must be flexible, and revised to meet changing conditions in the stand and landowner objectives. Private consultants, and in some districts OMNR foresters, can assist in developing management plans that will help achieve these objectives.

REVIEW

1. Forestry continues to be vital to both Canada's and Ontario's economy.
2. Trees are used for shelter/shade, site rehabilitation, aesthetics, wildlife habitat, and wood/fruit products.
3. Trees are one component of an integral life web within a forest. All types of management and non-management affect this web and its components. Woodlot management must take this into consideration.
4. Woodlots can be managed for many purposes at one time. These may include timber, fuelwood, maple syrup, wildlife, and/or recreation.
5. Integrated resource management (IRM) is the most recent forest management philosophy and involves managing the forest for more than one resource at a time.
6. Good woodlot management considers landowner objectives, current state of the woodlot, current market values, site condition, site potential, and the forest ecosystem.
7. The objectives of good woodlot management should include working towards the landowner's objectives, providing sufficient high quality growing stock, preventing inappropriate harvesting, protecting the stand from fire, grazing and other damage, enhancing wildlife habitat, and providing soil and water conservation.
8. A management plan must be flexible to meet the changing conditions of the stand and landowner objectives.

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Chapter 2

TREE IDENTIFICATION

BASIC TREE CLASSIFICATIONS

Tree identification (**dendrology**) is fundamental to forest management. Some of the many field guides available to help with the task are given in the selected References at the end of this chapter. Such guides generally provide a description and illustration for individual tree species along with a key to their identification. Often these guides describe trees and shrubs that are found naturally in Canada or Ontario, but do not include the many horticulturally bred species, or species from other regions. Trees planted outside their native region are called **exotics**. Some exotics are included among native trees either because they are commonly planted for forestry purposes (e.g. scots pine), or have escaped from urban areas and now form wild populations (e.g. tree of heaven). Horticultural books are available from nurseries to help with identification of exotics. To save a lot of frustration when trying to learn native species, tree identification practise should start in natural wooded areas. City parks and lawns are often planted with exotic species.

CONIFERS AND BROAD-LEAVES

One of the most basic ways of classifying trees is to categorize them as conifer or broad-leaved. Several other terms for these two groups of trees are often incorrectly used interchangeably:

conifers (cones and needles)	broad-leaved trees
evergreens (keep leaves year round)	deciduous (lose leaves annually in winter)
softwoods (refers to conifers)	hardwoods

The following are some sources of confusion with these terms.

- i) There are hardwoods such as poplar which wood is soft, and soft woods such as jack pine which wood is hard.
- ii) Tamarack (larch) is a conifer that is deciduous. It loses all its needles in the fall. Madrona (native to British Columbia) is an evergreen broad-leaved species. It does not lose its leaves in winter.

- iii) Conifers do lose their leaves, but not all at once. Needles normally live between 2 and 20 years.
- iv) Although cedar is considered a conifer, its cone is berry-like in appearance. Alder, a non-conifer, produces a cone-like fruiting body.

COMMON (OR LOCAL) TREE NAMES VS. BOTANICAL NAMES

For more precise classification, trees are commonly identified by species. Most species have a common name by which they are known throughout a particular region. They also have a scientific or Latin name. While common names are familiar to people, scientific names are unique to the species, do not vary as much over time, and are recognized internationally.

A Latin name consists of two words: the generic name (genus) and the specific name (species). Neither word on its own identifies the species. Note that only the first word is capitalized and both are either underlined or in italics. The scientific name is followed by the scientific authority: the name, or abbreviation of the name, of the person(s) who identified and classified the species.

Example 1.

white pine Pinus strobus L.

Pinus - genus -- with a capital

strobus - species -- small letter

L. - the botanical author, honoured in this way - L for Linnaeus

TREE IDENTIFICATION FEATURES

Tree species are identified according to differences in their features. Having several characteristics on which to base identification is important for several reasons: 1) some features may not be available either because of the season or because the specimen is no longer attached to the tree, 2) some species are indistinguishable by some features, or 3) the usual identification feature is atypical possibly due to site conditions. Many circumstances can arise where several characteristics may be needed to identify a species. Each of the following features commonly used to distinguish trees will be dealt with individually:

- a) Leaves - Conifers: number of needles in a bundle, and needle length and shape
- Broad-leaved: size, shape, margin, leaf attachment, venation, colour, texture and hair

- b) Twigs - opposite or alternate branching, hair, bundle scars, form (thick or thin), hair and colour
- c) Buds - arrangement, scales, colour, hair, size, shape, appressed or divergent, terminal versus lateral buds and pubescence
- d) Bark - texture (smooth, flaky, ridged), pattern, colour, and lenticels
- e) Flowers, Catkins, Cones or Fruit
- f) Form - the overall shape of the tree (e.g. balsam is spire-shaped, elm is fan- or umbrella-shaped)
- g) Site - not distinctive, but a helpful indicator
- h) Smell - sometimes distinctive (e.g. cedar)

a) LEAVES

Conifers

The conifers, with their distinctive needle-like leaves, can be distinguished by the length of needles, the number of needles in a cluster, and whether the needles are flat or 3 or more sided. The needles of spruce trees are very similar, so to differentiate between spruce species requires other features such as a twig or cone. Scale-like leaves are characteristic of cedars, although there are many exotic juniper species to confuse the untrained eye.

Broad-leaves

LEAF SHAPE

Broad-leaves trees are most commonly recognized by their leaves. Leaves may be categorized by whether and how they are divided into leaflets. If the flattened part of the leaf called the **blade** consists of a single, undivided sheet, it is called **simple** (Fig. 2.1). Sugar maple and beech leaves are simple. If the leaf is divided into several leaflets, as in ash, the leaf is **compound**.

Compound leaves are further subdivided according to how the leaflets are arranged (Fig. 2.1). **Trifoliate** leaves are compound leaves with three leaflets such as those of the hop-tree. Horse chestnut is an example of a **palmately** compound leaf because all the leaflets radiate from one point. Ash leaves have leaflets that branch from a central stalk giving them **pinnately** compound leaf structure. Trees such as black locust with doubly compound leaves are called **bipinnate**. Look for a bud on the twig where the leaf is attached, or for the **petiole** (leaf stalk) to enlarge where it attaches to the twig to be sure you are looking at the whole leaf and not just a leaflet.

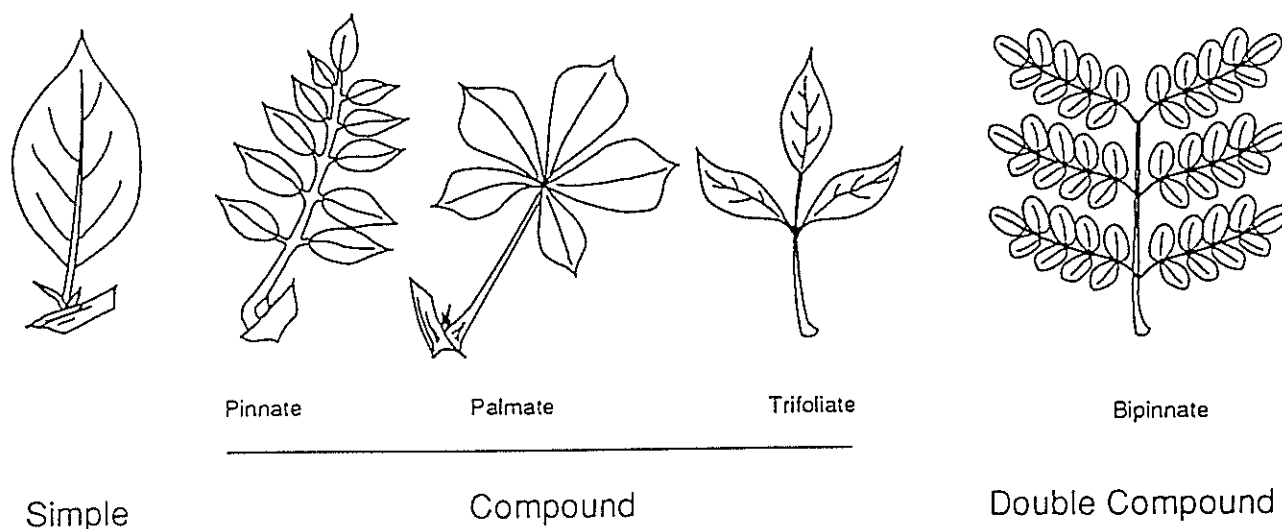


Figure 2.1. Compound and Simple Leaves

Many terms have been coined to describe the shape of leaves and the roughness of their margins. Leaf shape can range from round to long and narrow. Shape is unique for most species, although there is variation among the leaves on any given tree. Some characteristics to note are where the leaf is broadest, how its length compares to its width and its overall shape (Fig. 2.2). Leaf margins can be entire (smooth), serrated (small, sharp toothed, double toothed or lobed (deeply indented) (Fig. 2.3). The leaf characteristics covered so far will often be enough to identify a tree.

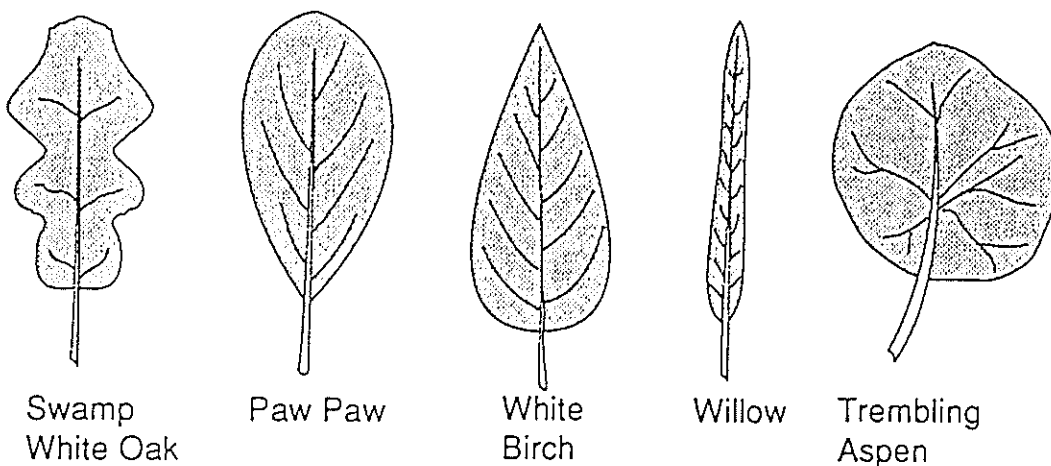


Figure 2.2. Sample variations in leaf shape

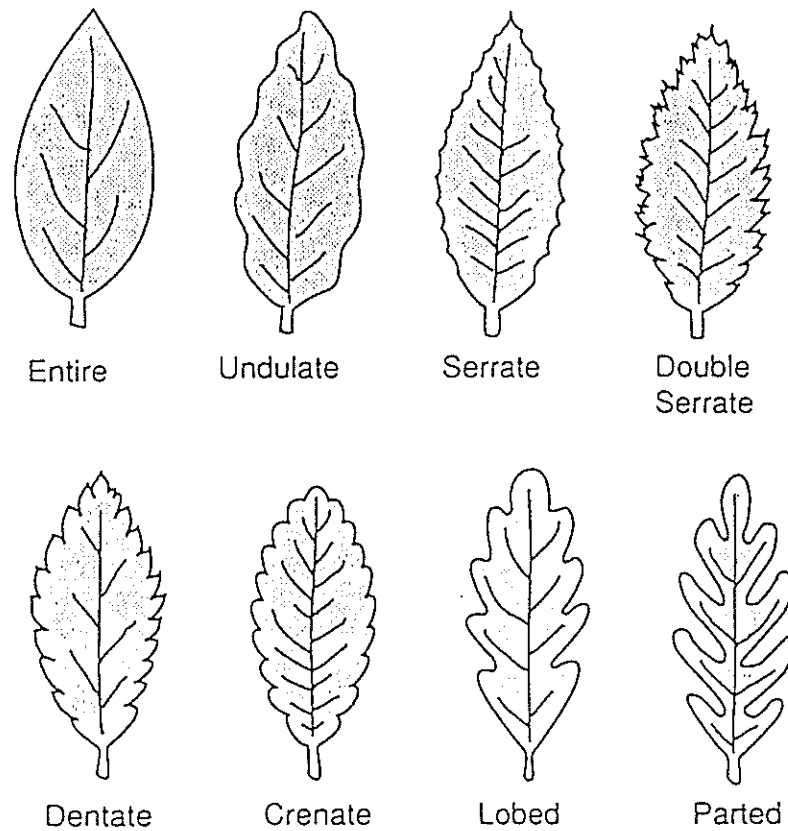


Figure 2.3. Types of Leaf Margins

LEAF ATTACHMENT

Leaves can also be described according to how they are attached to the twig. A **node** is a slightly enlarged area of a twig where leaves, buds, and branches originate. If two leaves arise from the same node their arrangement is **opposite**, whereas if there is only one leaf or branch per node the arrangement is **alternate**. The leaf arrangement is called **whorled** if many leaves are attached around a single node (Fig. 2.4). Maples and ashes show opposite branching, while most other trees have alternate branching.

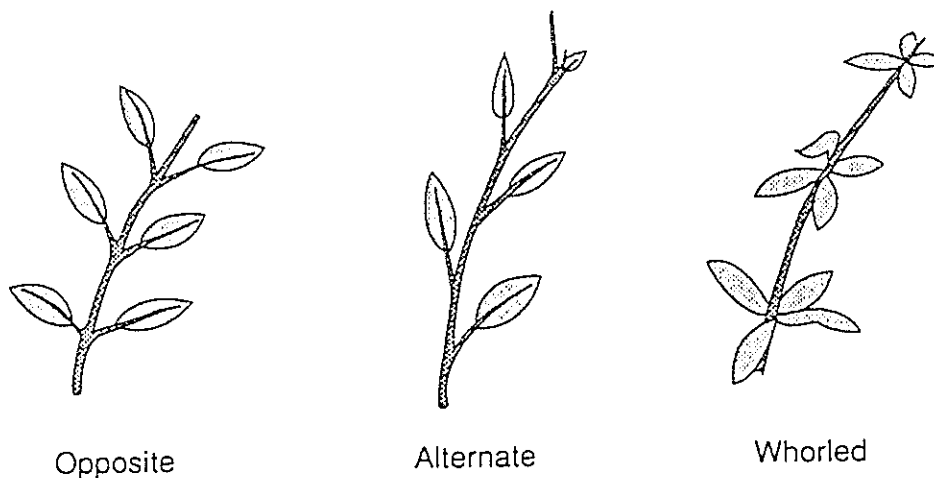


Figure 2.4. Types of Leaf Attachments

The length or presence of a petiole attaching leaf to branch, or leaflet to central stalk, can also assist with identification. A sessile leaf/leaflet is attached more or less directly to the stem with no petiole, while a **petiolate** one is supported by a petiole. This feature is commonly used to help distinguish among the ashes, since white ash leaflets have a very long petiole and black ash leaflets are sessile (Fig. 2.5).



Figure 2.5. Petiolate vs. sessile

LEAF VENATION

Most leaves also have a distinct **venation** pattern. The veins are often most clearly visible on the underside of the leaf where the veins usually protrude slightly. Whether venation is **pinnate**, or **palmate**, (Fig. 2.6) and where the veins fork are indicative of the species. Leaves that have a central vein that give rise smaller veins are said to be pinnate. In palmate leaves, the veins spread out from a single point at the base of the leaf.

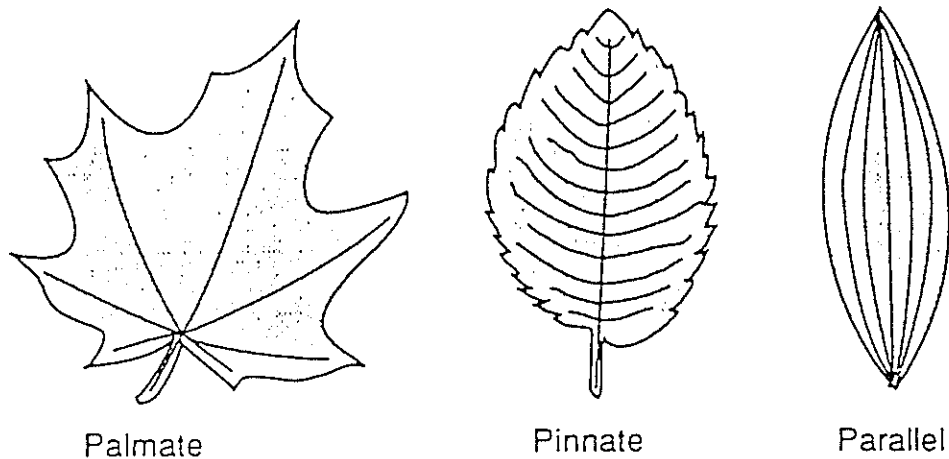


Figure 2.6. Types of leaf venation

OTHER CHARACTERISTICS

Other traits which may be helpful in identifying tree leaves are the colour, texture, and the presence or absence of hair and stipules. Stipules are tiny, almost leaf-shaped growths at the base of leaves or buds. Leaf colour is not unique, but can be useful for both summer and fall identification. For example, some trees such as trembling aspen have leaves that are darker on the upper surface than the lower surface. In autumn birch trees turn yellow, while oaks turn burgundy or brown.

Leaf texture also varies among species; some leaves are smooth and glossy like aspen, while others are very rough to the touch, like red elm. The presence of hair can affect the texture of a leaf by making it fuzzy, velvety, or prickly to the touch depending on the type and density of the hair. The location and type of pubescence, or hairiness, is species specific. For example, swamp white oak has velvety lower leaf surfaces and black cherry has orange hairs along the centre vein of lower leaf surfaces.

b) TWIGS

Twigs with buds are the most distinctive of all features by which to identify trees. Not as much variation is found in buds within a species as there is in leaves, and the difference in buds among species is consistently greater than in leaves. For the purpose of identification, tree guides usually describe the twigs in their winter state. Some of the twig characteristics to watch for are colour, hair, diameter and, in the case of yellow birch, taste.

Buds have many species distinctive characteristics. These can include the size, colour, arrangement and position of the buds; the size, hairiness, number, colour, and arrangement of the **bud scales**; and the appearance of the **leaf scar**, which is found where the previous years leaf fell off (Fig. 2.7).

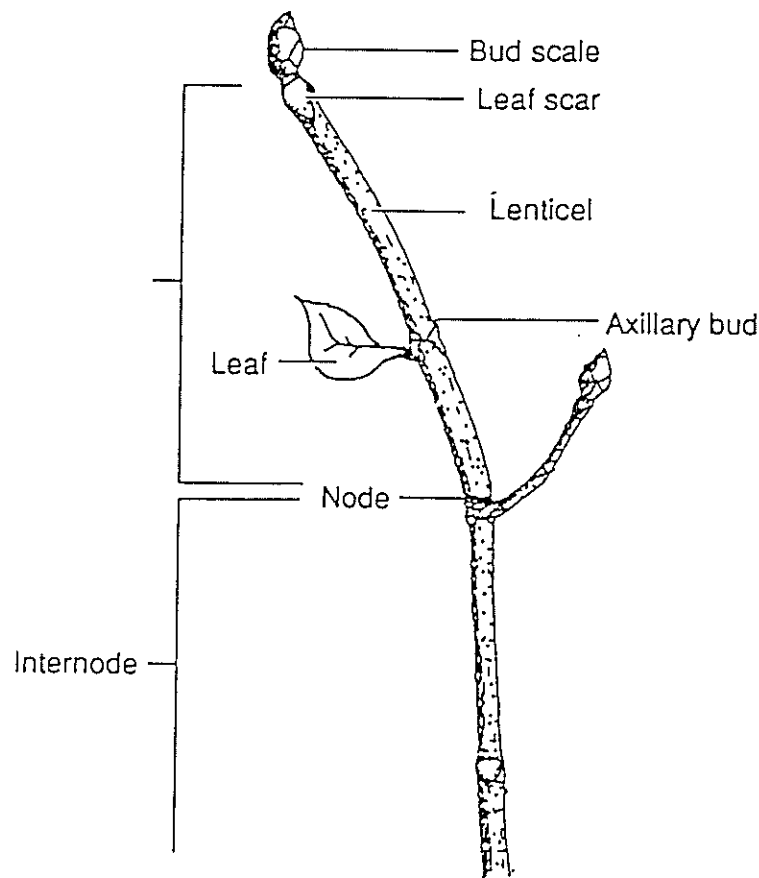


Figure 2.7. Twig

c) BARK

The tree bark is not particularly distinctive when the tree is young, but becomes more so as it matures. Once bark patterns become familiar, it is easy to recognize mature trees by their bark. For example, the smooth grey bark of a beech tree is very different from the flaky black bark of a cherry tree or the deeply fissured bark of walnut. Distinctive dark coloured lines or dots on the bark of cherry, birch and alder trees are **lenticels**. These are used for air exchange in young trees. As the tree grows, the lenticels will sometimes stretch forming characteristic marks on the bark. The colour of the bark is helpful, but variable, and can be stained with pollution.

d) FLOWERS AND FRUIT

While flowers are species specific, they are not usually used for tree identification because they are only present for a short time of the year. Fruit, consisting of a seed or seeds and its associated parts, is species specific and can be used during certain times of the year to identify trees. Some of the characteristics to watch for are type, shape, size, how they open to release the seeds, appearance of the pod, number of seeds in a pod, colour and sometimes taste. Figure 2.8 shows some of the different types of fruiting bodies found on trees and shrubs.

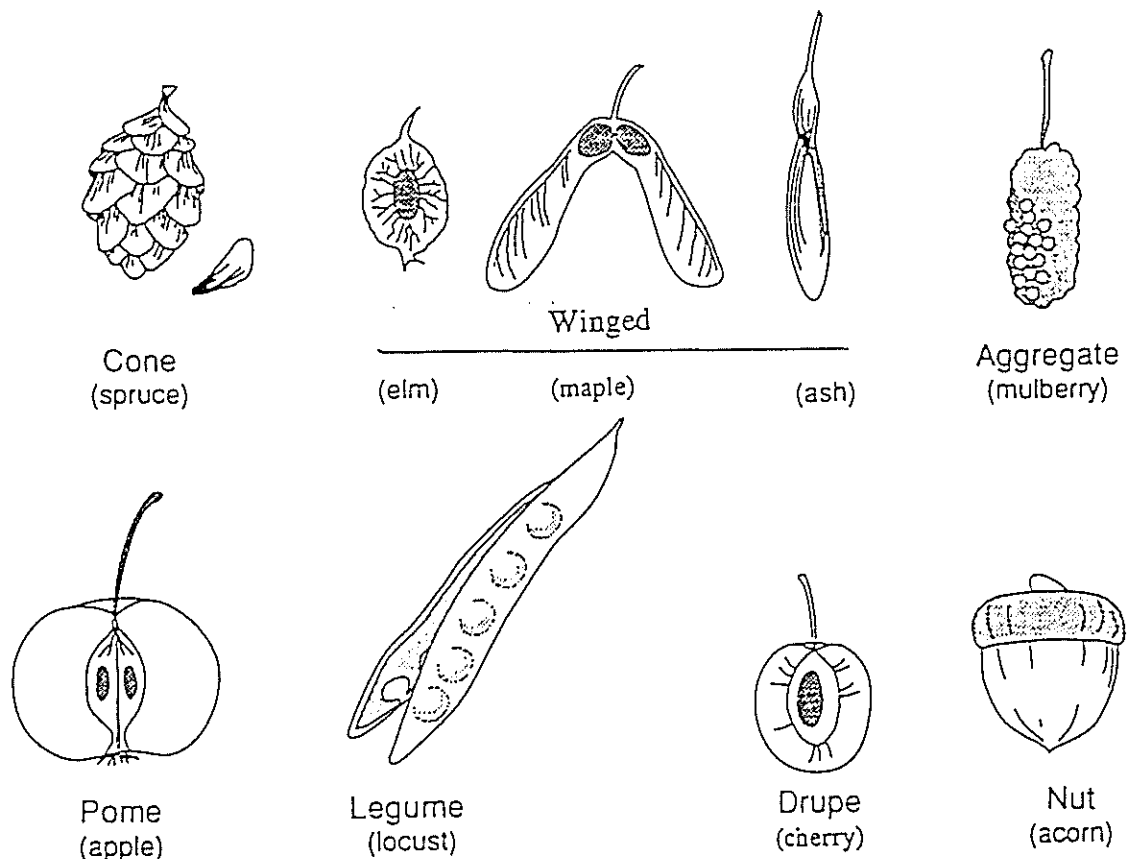


Figure 2.8. Sample fruit bodies

e) SITE/HABITAT

Trees are generally found within a particular range and under particular site conditions. While site is not a fool proof method of identification, it can be a useful indicator. For example, one would not expect to find a walnut tree in a northern Ontario forest, or a swamp white oak on the crest of a dry, sandy hill. Range and site are not strict. However, with this kept in mind, they make a useful tool.

MAKING A LEAF COLLECTION

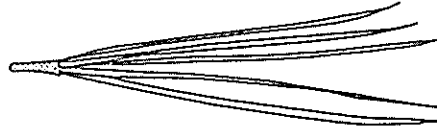
One way to learn tree species is to make a leaf collection. Identifying leaves and twigs is easiest in the field while you have the whole tree to examine. Therefore, samples should be identified and labelled in the field to minimize confusion later. Leaves are best if pressed immediately in a leaf press, before they have a chance to wilt or get damaged in transport. A simple leaf press may consist of a telephone book, while a formal leaf press is composed of alternating layers of absorbent paper and cardboard (or something hard and smooth) strapped firmly between pieces of plywood with adjustable belts (a piece of inner tubing works well). A leaf press must keep leaves flat and allow them to dry.

When pressing leaves as specimens, it is important to be aware of and preserve the identifying characteristics as carefully as possible. This means pressing whole clusters of needles for pines, pressing broad-leaf margins carefully, including a twig with needles for spruce trees, and including a turned over leaf for trees such as swamp white oak, which are characterized by pubescence or venation. Including the location of the tree, a twig with buds, seeds, catkin, cone or fruit with the leaf specimens may help confirm identification and help make these features familiar. Creating a leaf collection not only offers the experience of identifying trees, but also provides a useful reference guide.

USING A KEY

Keys are used to guide the user to the correct identification of a tree by process of elimination. Keys come in many styles, but the principle of their use remains the same. Two types of keys are given below, along with an example of how to use them. The user chooses from successive pairs of alternatives, eliminating some trees at each step, until there is only one tree, or family of trees, meeting the pathway of criteria. Starting at the beginning of the key, the user compares the characteristics of their material to the alternatives offered. Each response eliminates some species and leads to the next query. Once reaching the end of the path, the user should look up a more complete description of the answer and compare it to the material to ensure the material was keyed correctly.

Suppose you find a tree with leaves that look like this:



Using the first key (A) read through the first option, 1a. The leaves we are looking at are a not scale-like so look at your second option 1b. These leaves are needles, so you move in and choose between options 3a and 3b. These needles are not single, but in clusters so looking below 3b, you then choose between 6a and 6b. They all appear clustered so you choose between 7a, 7b, and 7c. There are 5 needles to a cluster so these needles probably came from a white pine.

(A) Key to the Conifers

- 1a Leaves scale-like, seldom more than 1.5 mm (18th inch) long, arranged in opposite pairs completely concealing the twig; occasionally some twigs present with longer leaves in 2's or 3's.
 - 2a Leaf-covered twigs flattish; successive pairs of needles not shaped alike; produces a small cone -- WHITE CEDAR
 - 2b Leaf-covered twigs 4-sided, successive pairs of needles same shape; produces berry type fruit -- RED CEDAR
- 1b Leaves needle-like or linear, not scale-like
 - 3a All leaves singly placed, linear
 - 4a Leaves flat
 - 5a Branchlets roughened by woody bases of fallen leaves -- HEMLOCK
 - 5b Branchlets smooth, leaf scars circular -- BALSAM FIR
 - 4b Leaves four-sided - SPRUCE
 - 3b Leaves needle-like and clustered
 - 6a Some leaves clustered, others single -- LARCH
 - 6b All leaves clustered
 - 7a Clusters of 5 needles -- WHITE PINE
 - 7b Clusters of 3 needles -- PITCH PINE
 - 7c Clusters of 2 needles
 - 8a Needles 10-15 cm (4-5 in.) long -- RED PINE
 - 8b Needles 3-6 cm (1.5-2.5 in.) long
 - 9a Needles with spiral twist, orange bark -- SCOTCH PINE
 - 9b Needles form V pattern and are not twisted, grey bark -- JACK PINE

[illegible][illegible][illegible]

REVIEW

1. Trees may be identified by the distinguishing characteristics of their leaves, twigs, bark, flowers, fruit, form and habitat.
2. Numerous tree guides and keys are available to aid in the identification of tree species native to Canada.
3. Making a leaf collection is a useful way to learn the intricacies of tree identification.

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Chapter 3

THE PHYSICAL ENVIRONMENT AND FORESTS

James A. Simpson

This chapter is not intended to provide all the information needed by a forest or woodlot manager to make the best management decisions. Instead, it is a brief summary of some of the more important physical factors and some examples of how these factors are related. However, there is no substitute for experience. An awareness of the complexities of soil and site relationships will assist the manager in making better decisions help them understand the causes of both successes and failures of forestry operations. With this in mind, this chapter will present a brief geographical history of southern Ontario. As well, it will discuss aspects of soil and climate and how these relate to site productivity for trees.

Glaciation has been a major influence on the landscape and soils of southern Ontario. Southern Ontario has had at least four major periods of glacial activity and virtually all of the landscape seen today is the result of the last glaciation and subsequent erosion and deposition. The last period of glaciation, known as the Wisconsinan period, began its retreat from southern Ontario 10,000 to 12,000 years ago. Subsequently, a substantial proportion of the soils were inundated or sorted by glacial meltwaters. Many of these soil deposits were also subject to periglacial winds prior to being invaded by vegetation. Thus, the processes of ice, water and wind have left a complex of deposits with distinctive soils and characteristics, each having important implications for forest growth.

The concept of "site" integrates the influences of three abiotic factors: soils, climate, and geography. These three factors are highly interrelated since soil development is dependent upon climatic and physiographic influences. An understanding of site is essential to understanding and working with forest ecosystems. Since elements essential for tree growth always flow down hill with soil and water, site conditions are generally better in mid to lower slope positions than in higher ones. Topsoil and associated nutrients are constantly moving downslope and tend to accumulate lower on the slopes. This difference in site quality leads to the observation that sometimes trees at the bottom of a slope grow taller than ones at the top, often resulting in a level canopy despite undulating topography.

Since each tree species has a specific range of site conditions that it grows best on, it should be easy to see that an understanding of site is critical when making forestry decisions. This chapter briefly explains important aspects of site quality and their importance.

GLACIATION

During the past ice age, most of Ontario was covered by ice. As the glaciers moved forward they dislodged and accumulated fragments of rock and soil. This material was churned in the slurry at the bottom of the glacier, and ground into smaller particles. Where the glaciers passed over hard bedrock, such as the granites of the Canadian Shield, little material was accumulated and the bedrock was often scraped bare. In southwestern Ontario the bedrock was composed of much softer material such as limestones and shales. The glaciers were able to pick up and re-deposit large amounts of this softer material. The glaciers deposited the material (**till**) they carried in a number of characteristic ways, which created distinct landforms or depositional features: moraines, drumlins and till plains. In many cases, the till was modified by water and/or wind, resulting in a number of other landforms and soils (e.g., eskers, outwash sands, dunes, and **lacustrine** (lake) and **marine** (sea) deposits).

Water deposited materials are sorted by size, which means that the material is of similar sizes, whereas till material is made up of mixtures of particle sizes, from clay to stones. Stones are rounded when deposited by water and angular when found in till. Depending on the speed the water was moving when the material was deposited, certain sizes of particles were deposited. If the water was moving quickly, only stones or boulders may have been left. As the rate of flow decreased gravels and sands were deposited. Finally, in very slow moving water, such as in lakes and seas, silts and clays fall out of suspension.

As the glaciers melted, rivers formed under the ice and the coarse materials (sand, gravel and stones) that were not washed away by the meltwater were deposited on the riverbottom creating **eskers**. As the water drained away from the glaciers, **outwash deposits**, generally consisting of stratified, or well-sorted, sands were deposited. Where drainage patterns formed rivers, spillways were created, and where the water formed lakes and seas, fine lacustrine and marine deposits were formed. As the glaciers retreated, many of the original depositional features were reworked by meltwater and winds. In southern Ontario, many of the eskers were washed away as the meltwater rushed toward the seas, and without protective vegetation, sandy outwash deposits were blown around and redeposited as dunes.

This information is important in forestry as each type of deposit will have a distinct influence on tree growth. Depending on the materials the glacier deposited, soil derived from till can be extremely productive. If till plains are fertile, they are generally used for agriculture so forests in southern Ontario are usually found where the soil is too wet, too dry or too stony for agriculture. Since silts, and especially clay, hold most of the nutrients in the soil, outwash sands usually have few nutrients, and are often well drained to the point of being droughty. Tree species that are well adapted to these conditions, such as pine, often grow well on outwash deposits. A soil with a high clay content may be fertile, but may also be poorly drained.

GLACIAL DEPOSITS

Moraines

Moraines are composed of the solid material the glacier was carrying. **Terminal** or end moraines were formed at the limit of a glacial advance by an ice lobe as it ploughed material at its base. Where the glacial front was relatively stationary, a substantial amount of material accumulated. Ground moraines (e.g., till plains) formed during a relatively constant retreat of a glacier. The material laid down may be composed of silts, sands and clays as well as larger fragments depending upon the material previously accumulated by the glacier. Till plains are generally level and are often capped by a thin veneer of sand or silt, the result of meltwater or periglacial winds.

Kames

Kame moraines were formed between the lobes of two convergent glacial lobes or when large chunks of a glacier broke off. In the first case the resulting landform is a discontinuous ridge of sands and gravels. In the second case, irregular mounds of till were dumped as the stranded chunks of glacier melted. Kames have generally been reworked by water and can often be characterized by their stratified sands and silts.

Drumlins

From the air, drumlins are tear-drop or spoon shaped mounds which usually occur in clusters. They were formed as the glaciers advanced and consist of till materials with a steep side rising to an apex, then gently tapering off in the direction the glacier was moving. The gently sloping portions of many drumlins have largely been cleared for agriculture. However, along the short, steep axis many drumlins are still under native forest cover. Several good examples of drumlins can be found in and around Guelph and Peterborough.

Eskers

Eskers were formed by rivers that carried meltwater from underneath a glacier. As the water flowed it carried away the finer sands and silts, leaving poorly sorted deposits of coarse sand, gravel and larger stones. Eskers now appear in the landscape as inverted rivers or serpentine ridges. Many eskers have been mined for gravel. In southern Ontario, many of the eskers were washed away by meltwaters.

Outwash

Outwash plains were formed by chutes of meltwater flowing off the glacier. This water carried both coarse and fine material. The silts and clays remained in suspension until the speed of the water was reduced as it fanned out across the landscape or found its way into a spillway. The sands were deposited first because the individual grains were too heavy for the water to carry for a great distance. Outwash deposits are well sorted (stratified) and have level to gently rolling (fluted) topography.

Spillways

As the glaciers melted the meltwater followed channels which became rivers. These channels and rivers are known as spillways. Many of the rivers that exist today follow these spillways. These deposits are characterized by well rounded stony bottoms, terraced banks and, often, kame deposits. These are known as glaciofluvial deposits.

Glacial lakes

Glacial lake deposits (glaciolacustrine) are characterized by relatively deep, well stratified deposits of silt and clay, often alternating in thin layers. However, where deeper lakes existed the deposits may be more uniformly clay. These deposits are very level, which restricts surface runoff. A good example of this type of deposit can be found in Kent and Essex Counties.

Glacial Seas

These are much the same as glaciolacustrine deposits except the waters were saline. Clay size particles, which are also clay minerals, are generally platelike in form. Under fresh water conditions these platelike particles will lay flat, one atop the other. However, in a marine environment this is not necessarily the case. The individual particles may tend towards a pattern of stacking similar to a cardhouse. These soils, as can be found in the Nation River valley south of Ottawa, are subject to collapse, especially when saturated and subject to mechanical stress.

Post Glacial Deposits

Over the last 10,000 to 12,000 years the landscape has undergone a variety of processes which influence soil development, including human activity. However, natural processes are always at work moving soils around and influencing the landscape. **Alluvial** deposits are sediments deposited by flowing water, generally associated with spring floods. These are composed primarily of silt and can add fertility to the soil. **Colluvial** deposits are those that result from material moving downslope either by water or gravity. **Aeolian** deposits are windblown sands or silts. When these deposits are distinct, loess soils are formed from silty aeolian deposits and sandy deposits often form dunes.

EVOLUTION OF TREE SPECIES¹

Many of the tree species that currently make up Ontario's forests originated in ancient times. The **angiosperms**, broad-leaved flowering species commonly call "hardwoods" appeared and greatly expanded their ranges in the Cretaceous Period, 135 million to 65 million years BP (before present) and may have originated even earlier (see Table 5.1). Many of the species that are familiar to us today, such as certain poplars, willows, alders, birches, beeches, oaks, walnuts, sassafras, cherries, hackberry, magnolias, gums, sycamores and the tulip tree arose long ago.

¹ Adapted from *Evolution of Tree Species* by Alan G. Gordon. In: *Legacy: The Natural History of Ontario*. J.B. Theberge (ed.). McLelland and Stewart. 1991.

Table 3.1. Geological time table of the evolution of tree species.

Millions of years BP	Era	Period	Plant life present
65-136	Mesozoic	Cretaceous	Angiosperms abundant by close of period.
136-195		Jurassic	Gymnosperms, especially cycads and ferns. Climax in dinosaur population.
195-225		Triassic	Forests of gymnosperms and ferns.
230-280	Paleozoic	Permian	Origin of conifers and possible origin of angiosperms; earlier forest types decline.
280-345		Carboniferous Pennsylvanian Mississippian	Great swamp forests of ferns, club mosses, gymnosperms and horsetails.
345-395		Devonian	Rise of land plants.
395-440		Silurian	
440-500		Ordovician	
500-600		Cambrian	
		Precambrian	Earliest known fossils

The conifers or cone-bearing trees commonly called "softwoods" arose even earlier, beginning near the end of the Paleozoic Era 230 million years BP, and expanding through the early and mid Mesozoic Era to have worldwide distribution by the mid Cretaceous Period. Ancestors of the family *Pinaceae*, particularly the genus *Pinus*, the pines, were well established by the Cretaceous. On the basis of available fossils, other genera of this family - the spruces, hemlocks, firs and larches - with species the same or similar to the species we know today, are thought to have arisen and radiated (spread) after the pines. They are therefore considered more modern.

Most of the genera of trees in Ontario today originated and radiated from their place of origin before continental drift isolated North America. Many other species in all continents however, originated after the continents separated. Dispersal was made possible by two land bridges between North America and Eurasia. Many of the early conifers, as well as many angiosperms, dispersed across these bridges. The land bridges help explain some of the genetic similarities that are found in trees on opposite sides of the oceans.

Another influence on range expansion of tree species is competition. Many species are able to grow in a given area, but few will dominate sufficiently well to persist. A fact not well appreciated is the intensity of the age-old struggle between the **gymnosperms** - conifers and their allies - and the angiosperm hardwoods, since the coming of the latter. This battle continues in

the modern forest today, and humans now participate influentially in it. Unfortunately the conifers continue to lose. In the Jurassic (195 to 136 million years BP) there were more genera and species of conifers than we shall ever know again.

By the middle of the Cretaceous Period, the angiosperm hardwoods, spreading quite rapidly after their recent origins, had become the dominant group of seed plants. The conifers and their relatives, which had originated much earlier and dominated until the mid Cretaceous, lost many genera and species through competition from the hardwoods. Angiosperm species today are many times more abundant in the world than the conifers and their allies. Conifers usually have become restricted by the hardwoods to more stressed sites where the hardwoods cannot easily follow. Conifers survive competition best on cold, wet, hot and dry sites. Hardwoods generally hold the better middle ground.

One further factor, the herbivorous impact of dinosaurs, influenced forever the struggle between gymnosperm conifers and the angiosperm hardwoods, tipping the balance in favour of the hardwoods. Millions of years of conifer browsing by high-feeding dinosaurs before hardwoods evolved clearly did not inhibit the conifers, which then were at their peak numbers of species. But at the beginning of the Cretaceous Period, many of the large dinosaurs that browsed at heights of eight to fourteen metres were replaced by smaller species that browsed and cropped much lower down.

The crowns of trees that were browsed high up were mature and full. There was usually enough vegetation left for persistent growth and reproduction. However, with the switch to low-feeding dinosaurs, regeneration was eaten. When coniferous regeneration is growing in the presence of hardwood regeneration and its leaders are clipped, usually the coniferous seedlings lose their height dominance to the hardwoods and die. Young conifers today whose leaders are browsed by rabbits and deer suffer the same fate. Dinosaurs also ate hardwoods, but these are better able to survive browsing. Hardwoods can often sprout new shoots from their rootstocks, something few conifers can do.

It is very interesting to consider how interactions such as these that took place millions of years ago could have such an effect on the types of forests we find in North America today.

SOIL NUTRIENTS

MACRONUTRIENTS

Macronutrients are nutrients required in relatively large amounts and are essential for plant growth. These are: nitrogen; phosphorus; potassium; calcium; magnesium; sulphur; carbon; hydrogen; and oxygen. The latter three elements are largely derived from air and water. The others are derived from soil minerals and organic matter. It is these nutrients that are discussed here.

Nitrogen

Nitrogen is one of the most important nutrients for plant growth. Plants undernourished in nitrogen have poor growth and chlorotic (yellow or yellowish-green) leaves. Although nitrogen levels are rarely too high in a field situation, an over-supply of nitrogen, possibly from fertilization, will encourage excessive vegetative growth, may delay maturity or hardening off, and may create weak stems. Nitrogen is required for the utilization of potassium, phosphorus and other nutrients.

In mineral soils there are three major forms of nitrogen: organic N, ammonium (NH_4^+) fixed in clay minerals, and soluble inorganic ammonium and nitrate (NO_3^-) compounds. In a process called nitrification, ammonium is converted to nitrite (NO_2^-), generally by the bacteria *Nitrosomonas*, then to nitrate, by *Nitrobacter*. There is usually little accumulation of nitrite which is fortunate as it is poisonous to plants. Ammonium may also be taken up directly by plants. Young plants in particular seem to utilize ammonium quite efficiently, however, most species require at least some nitrate for optimum growth.

Nitrate is readily utilized by both plants and microorganisms. Microorganisms have a much higher capacity to use nitrate than plants, if a carbon source is present in the soil. Nitrogen associated with organic matter is said to be immobilized since it is unavailable for plant use. This rapid immobilization of nitrate by microorganisms can induce early season nitrogen deficits for plants and trees. For plants to use it, it must first be converted to an inorganic form. This process is called **mineralization** and is maximized in well drained and aerated soils with plenty of basic cations present. Mineralization supplies substantial amounts of nitrogen during the growing season.

Nitrate is highly soluble in water and is easily lost in groundwater. Excessive fertilization is therefore a major cause of groundwater contamination with nitrate. Denitrification (the gaseous loss of nitrogen) is also a source of nitrate losses. This process is enhanced by conditions of saturation or poor aeration.

Some plants have developed symbiotic relationships with microorganisms that convert nitrogen gas (N_2) from the atmosphere. This process is called **nitrogen fixation**. Legumes like soybeans or black locust form nodules with *Rhizobium* bacteria and other actinorrhizal plants, such as alders, associate with fungi (Actinomycetes) to fix nitrogen. Nitrogen-fixing trees are important in forestry, particularly in site rehabilitation or reclamation. However, if plenty of nitrogen is available, these trees will utilize available nitrogen rather than fix it.

Clay minerals, such as vermiculite, illite and montmorillonite have a capacity to fix ammonium ions in their mineral structure. This ammonium becomes relatively unavailable and is released only as the clay particles weather. The fixation of ammonium occurs to a greater extent in the subsoil because the clay content tends to increase with depth.

Phosphorus

Phosphorus is required in almost every metabolic function of a plant. Phosphorus deficiency is expressed as retarded growth, reduced leaf size and the appearance of the red pigments (anthocyanins). Phosphorus toxicity is not a problem in a forest situation.

Phosphorus is only slightly soluble in soil water. As such, most of the phosphorus is unavailable to plants. Addition of phosphate fertilizers, even in large quantities, will not significantly alter the available phosphorus as it is rapidly fixed or converted to insoluble forms. In neutral and alkaline soils calcium generally reacts with phosphorus (forming various Apatite minerals) and in acid soils it reacts with iron and aluminum (forming various hydroxy phosphates). These mineral compounds are very stable and are only slowly weathered.

Although phosphorus is largely unavailable, plants still manage to take up sufficient quantities for sustained growth. This is largely due to the ability of plants to modify the soil environment immediately around the root (the rhizosphere). It is this ability that allows plants to dissolve small quantities of phosphorus-containing minerals.

Much of the soil phosphorus is associated with organic matter. Like nitrogen, it too must undergo mineralization to be available for plant use.

Potassium

Potassium, like phosphorus, is required in a wide variety of plant metabolic functions. Potassium deficiency can severely limit the rate of photosynthesis and starch synthesis. It is exhibited by the appearance of dry or scorched leaf margins and a chlorotic, mottled appearance of the leaves. Potassium toxicity almost never occurs, except through excessive fertilization.

Although potassium levels in the soil are generally high, relatively little is available for plant use at any one time. It is most often tightly bound in primary minerals or fixed within the lattice structure of clay minerals. Additions of potassium fertilizer are initially highly soluble. However, it is either rapidly fixed or lost through leaching.

Calcium

Requirements for calcium varies considerably between plants. It is used largely in the formation of cell walls. Deficiencies rarely occur on soils of calcareous origin and is of minor importance in trees growing on acidic soils.

Calcium is a constituent of many common soil minerals. It commonly reacts with phosphorus to form relatively insoluble precipitates. However, much of the calcium is exchangeably adsorbed onto colloid surfaces or exists in the soil solution.

Magnesium

Magnesium is much less abundant in soils than calcium and may be deficient in sandy or acid soils. Magnesium is derived from basic minerals such as olivines and micas. Like calcium, it is adsorbed onto colloid surfaces or exists in the soil solution.

Deficiency is characterized by interveinal chlorosis with the red and yellow pigments becoming dominant. Deficiencies are easily remedied by applying crushed dolomitic limestone.

Foliar application of magnesium will also provide a rapid response, but has little effect on the long term fertility of the soil.

Sulphur

Sulphur is required in every living cell, as it occurs in some amino acids, proteins and vitamins. Sulphur deficiency leads to small, spindly plants, chlorosis and, in the case of legumes, reduced nodulation. Sulphur toxicity is not generally observed. However, a continuously high amount of atmospheric sulphur dioxide from acid rain can cause permanent damage in trees, in addition to acidifying the soil.

Sulphur in the soil is derived from weathered minerals, atmospheric deposition and organically bound sulphur. Organically bound sulphur generally makes up the largest pool of sulphur in a soil. However, it is only slowly released as microbial action on the organic matter occurs.

In industrialized areas the atmospheric deposition may supply most of the sulphur requirements for plants. However, this is often accompanied by acidification of soils. While this is not a serious threat in areas where the soil has a high buffering capacity, the addition of acid precipitation can cause a variety of problems for plants in areas where the soils are of acidic nature.

MICRONUTRIENTS

Micronutrients are required in very small amounts but are essential for plants to complete their life cycle. These are: iron, manganese, zinc, boron, copper, chlorine, cobalt and molybdenum. These nutrients are generally found in very small quantities in the soil. Intensively managed soils may become deficient in some of these nutrients, but this is easily remedied through fertilization.

Micronutrient deficiencies generally occur under four conditions:

1. Sandy soils, which are generally low in all nutrients,
2. Organic soils, which are also low in several nutrients,
3. Very alkaline soils, where sufficient quantities may exist in unavailable forms, and
4. Areas where crop removal has depleted the nutrient.

Except in alkaline soils, fertilization can temporarily eliminate a deficiency. In alkaline soils, the addition of fertilizer to the soil will be of little or no benefit as the nutrients that are deficient will be rapidly converted to the unavailable form. However, foliar applications can eliminate this problem in the short term.

ORGANIC MATTER

Organic matter develops from decomposed plant and animal materials. The exact composition of organic matter is not well understood and varies from soil to soil. Because it aids

in holding individual grains of soil together, farmers know organic matter as "the glue that binds the soil". It also helps reduce erosion of surface soil, increase the rate of water infiltration, improve internal drainage, and increase soil nutrient retention.

Organic matter contains several nutrients essential to plants. Its role in nitrogen and phosphorus retention and release have already been mentioned. Organic matter also contains many micronutrients which are also released slowly as it breaks down. The large number of pH dependant negative charges found in organic matter are important sites in nutrient retention. Under neutral to alkaline conditions (pH 7 to 14) it has a high cation exchange capacity (CEC). However, as the pH decreases the CEC is reduced. Elements held on the surface of organic matter are easily dislodged and are readily available for plant use. Some elements are chelated, or very firmly bound, within the structure of organic matter. These elements are generally metals with a large number of positive charges.

SOIL STRUCTURE

Soil structure specifically describes the way soil particles are held together, generally described by their shape. Soils with good structure are sometimes referred to as having good **tilth**. Essentially a well structured soil will have a mix of pore sizes, from large to very small, and will easily crumble, but not disintegrate into individual grains. Loam soils generally fall into this category. The mix of grain sizes create a variety of pore sizes providing a balance between the rate of water infiltration, moisture holding capacity and internal drainage. Increasing the organic matter content of soils will also improve these features.

Soils which have no structure, such as pure sands or clays, are sometimes difficult to manage. Pure clays which have been previously poorly managed or compacted when wet by heavy machinery or livestock, often resemble modelling clay. The structure of such a soil is referred to as massive. These soils may be extremely difficult to plant and are subject to prolonged saturation which results in impeded root growth. Sands with no structure will be excessively drained, which means they will not retain enough water to regularly supply a plants needs. Tree establishment on these soils may be difficult without proper wind protection, either from cover crops or windbreaks. Examples of tree species adapted to these adverse site conditions are red pine (which prefers drier, nutrient poor sites, such as sands) and black ash (which grows well on wetter sites, such as clay and clay loam bottom land sites).

SOIL WATER

The infiltration, storage and movement of water in soil is controlled by soil texture and structure. Fine textured soils have a large number of very small pores. Water can move into these pores only slowly. Coarser textured soils have much larger pores and water can penetrate rapidly. Loam soils posses a mixture of pore sizes and are generally considered to have the best properties for moisture retention and drainage.

The depth of soil over bedrock or other impermeable layer strongly affects the movement and storage of water. Obviously, as the soil depth over bedrock decreases, so does the volume of pore space available to store water. Shallow soils are subject to regular and often prolonged drought stress. However, depressions in the underlying bedrock may accumulate drainage waters, so even in shallow soils, moist pockets may exist.

Soils which are more or less permanently saturated become **gleyed**, which refers to soil changes caused by reduced iron due to the low oxygen content of the water. Gleyed soils range in colour from blue-grey to purple. The mineral soil will commonly be overlain by deposits of undecomposed organic matter, such as in bogs and marshes. Soils with fluctuating water tables (periodic saturation) will have **mottles**. Mottles are different coloured coatings on the mineral surfaces resulting from the alternating oxidation and reduction of iron. Mottles are yellowish to orange in colour and differ from the natural or matrix colour of the soil. When the periods of saturation are prolonged the colours become stronger and the size of the mottles increases.

The depth to these zones of periodic saturation are important to root growth. Some species, such as willow, excel under conditions of periodic or even permanent saturation. However, in many plant species saturated conditions result in stunted growth and rapid aging of roots. However, in coarse textured soils, mottling may indicate improved moisture availability. The description of soil drainage ranges from very poor, which is saturated all of the time, to excessive, where virtually all the water is rapidly lost from the rooting zone. This is determined by soil texture, slope, slope position and depth of the mineral soil. It is reflected in the abundance of mottles or gley colours and the size and contrast of mottles (Fig. 3.1).

Moisture regime is a method of describing the potential moisture status of a soil. It combines the dominant texture, depth to bedrock and depth to mottles or gleying to provide a single index of water availability. Research has been able to relate the optimum moisture conditions required by different tree species to the moisture regime estimates. Moisture regime differs from drainage in that moisture regime accounts for moisture holding capacity. Drainage simply estimates the ability of a soil to lose excess water.

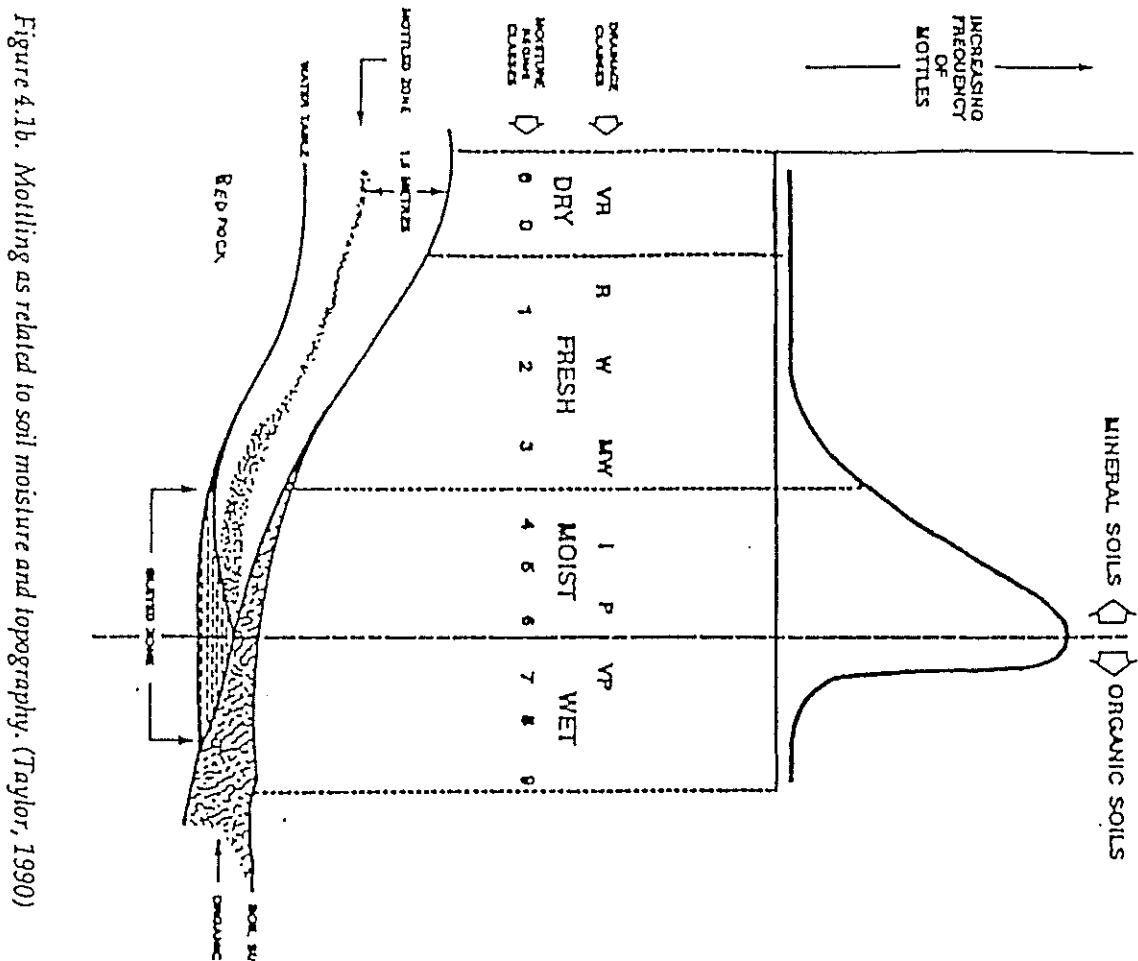


Figure 4.1a. Soil Drainage
(O.I.P. 1985)

Figure 4.1b. Molling as related to soil moisture and topography. (Taylor, 1990)

SOIL GENESIS

When the soils were first deposited they were generally very much the same from top to bottom. Over time processes of soil development, or **pedogenesis**, have been occurring. These processes are functions of climate, parent material, organisms, topography and time itself. All of these factors are inter-related. Topography and parent material are more or less constant in time. However, climate and the impact of organisms are always in a constant state of change. Topography is controlled by the shape of the underlying bedrock and the mode of soil deposition. Climate is affected by factors such as topography, proximity to large water bodies and latitude. The types and quantities of plant, animal and microbial organisms are influenced by all of these factors.

Weathering is the essential process of soil formation. It involves the breaking down of rock and the chemical release of its constituent minerals. This is commonly initiated by the relatively unweathered mineral material colonized by lichens, microorganisms and early successional plants. Lichens exude acids which dissolve rocks releasing chemical elements. As the lichens die they are incorporated into the young soil beginning the accumulation of organic matter. As this process continues the soil environment becomes more favourable for colonization by higher plants. Grasses and sedges are often among the first vascular plants to colonize a young soil.

As time progresses the appearance of distinct layers or **horizons** in the soil become apparent. For the purpose of classifying soils the extent and type of horizons that have developed are the main criteria. Horizons are formed either by the accumulation or loss of material. Surface horizons are given the designation of 'A'. Relatively unchanged parent material is designated as 'C'. The horizons in between are 'B' horizons. These designations are modified to indicate the type of loss or accumulation. For instance, 'h' denotes the accumulation of humus (organic matter) and 't' denotes accumulation of clay.

GEOGRAPHY AND CLIMATE

There are a variety of geographic features that affect tree growth and one another, and therefore, must be discussed together. Topography affects the movement of air, water and the amount of solar radiation received by trees. Latitude, altitude, large bodies of water, mountains and other large scale landforms all influence the movement of air masses, temperature, rainfall, etc. These are examples of macroclimate. Smaller changes in the landscape have much smaller, but significant, influence over local, or micro-, climates.

The movement of large air masses is generally controlled by the jet stream. Air masses that are directed from the north generally are cooler and carry little moisture as they have developed over the northern icefields. Conversely, air masses directed from the south are generally warmer and have a greater capacity to carry moisture. As an air mass moves across a large open body of water it absorbs moisture; the amount of moisture which can be absorbed is

controlled by the temperature of the air mass. The warmer the air mass, the more moisture it can hold.

A rain shadow is an area of lower rainfall on the lee side of a mountain range or major elevation change on the landscape. The Algonquin Dome and Rocky Mountains are examples of heights of land which have rain shadows on the east. As an air mass is forced to rise, the temperature decreases causing the capacity to hold moisture to be reduced. Once the air reaches its saturation points it will rain or snow. Once the air mass has moved over the obstruction and begins to descend the air will begin to warm and the moisture holding capacity will increase. As the air is no longer saturated it is unlikely that any precipitation will occur. This process is called orographic lifting.

The most pronounced effect like this in Canada occurs as air masses move from the Pacific Ocean, across the prairies and further eastward. Air masses that have developed over the ocean accumulate enormous quantities of moisture. As they move inland they are forced upwards by the Coastal Range which bounds the lower mainland of British Columbia. As the air rises it cools and large amounts of precipitation falls in this region. As the air mass continues its journey across the Western Cordilleras and the Rockies most of the remaining moisture is lost.

On the west side of the Coastal Range, temperatures are moderated by the ocean and rainfall is generally extremely high. This has led to the development of a specific forest coverytype, reminiscent of tropical rainforests. In the interior forests the rainfall is more moderate and temperatures have a wider range leading to the development of boreal and sub-boreal forest types.

Continuing into the Prairies there is little moisture accumulated and no geographical features to modify the air mass, therefore, little precipitation is likely to fall. This has lead to the development of grasslands as the dominant vegetational cover. There has not been any significant forest cover in this region since the retreat of the Wisconsinan glaciers.

This is an extreme example of how macroclimate is controlled by landform. However, the same process occurs as air masses travel over the Algonquin Dome into the Ottawa Valley. The Algonquin dome is a remnant of an ancient mountain range but is still considerably higher than the surrounding lands. As such, the west side of the region receives considerably more precipitation than the east.

The effect of the Great Lakes is no less significant than that of the Pacific Ocean. Air masses entering this region generally track from the northwest to the southeast or from the southwest to the northeast. The lakes also have a moderating effect on the local climates. This permits the ranges of more southerly species, like tulip trees, to extend north into southern Ontario.

The frost free period, or growing season, of an area is also an important consideration when selecting tree species to plant. Nursery stock that was grown from a seed source at the southern end of the species range may not adapt to a shorter growing season at the northern end of its range. Stock that originated in the northern range may initiate senescence much earlier in

the season than necessary if outplanted in the south, thus reducing the potential growth. An example of the effect of geography and water bodies on growing season is the twenty day difference in the growing season between Owen Sound and the Kolapore uplands at the top of the Niagara Escarpment, only a few kilometres away.

As previously mentioned, aspect and slope position are very important to tree growth, especially during establishment. Southerly aspects are subject to moisture stress during the summer as the rate of evapotranspiration can exceed the supply of soil water. This is due to the fact that the intensity of the solar radiation is considerably greater when the angle of the earth's surface approaches perpendicular to the sun's rays. Conversely, northerly aspects do not receive a large amount of solar radiation. Trees growing on north facing slopes may not become light saturated, and therefore, are not capable of maximizing photosynthetic potential.

Trees growing on southerly and westerly aspects are subject to 'Southwest Injury'. This is caused by the differential warming of the bark on the southwest side of a tree, which thaws the water in the outer part of the bole. This thawing and subsequent freezing can cause the bark and wood to split. This not only reduces the value of the wood but also creates a point of entry for insects and disease.

Slope position can affect the water and nutrient regime of a soil as well as affecting the flow of air. Water not held within the soil matrix will move downward following the path of least resistance and will tend to accumulate at lower slope positions. This water carries with it soluble nutrients which creates a gradient with respect to soil water and nutrients: low moisture, nutrient poor at the upper slope and nutrient rich, high moisture at the lower slope.

Cool air is denser than warm air, thus, it tends to sink. This accumulation of cool air in depressions increases the likelihood of frost, especially in the spring and fall. Trees growing on lower slope positions can be subjected to a shorter frost free period than those growing higher on the landscape. This is particularly important during establishment. Early in the first season of establishment, trees may not survive a frost due to a combination of stresses induced by transplanting. An early frost in the fall may injure or kill young trees if they have not yet initiated 'hardening-off'.

SOIL-SITE RELATIONSHIPS

There are no absolutes when discussing soil and site relationships. Therefore, the following discussion is based on a theoretical landscape from southern Ontario. Please note that where potential productivity is discussed, the authors are not making any inferences as to ecological productivity.

The illustration (Fig. 3.2) shows a varied topography with moisture regimes ranging from moderately dry to very moist (0-6). The soil may typically range from loamy to clay loam till except in the river floodplain where the till would be overlain by stratified silt and clay. The lowland mixed wood forest (right hand side of the illustration) typically develops in poorly drained areas subject to temporary inundation, especially in the spring and fall, and will generally

maintain a high water table throughout the year. This type of landscape is typical of terminal moraines.

Moving from left to right on the illustration, the first coertype is an upland mixedwood. This forest would likely be dominated by sugar maple with varying amounts of red oak, white ash, white pine and poplar depending on microsite and history. Poplar is a pioneer species and does not generally survive for very long, perhaps 60 - 80 years. However, some individuals may survive much longer and often make up a small component of older stands. White pine is a relatively long lived species, especially where the soil has good internal drainage but moisture is not limiting (e.g. toe slopes or cove sites). A moisture regime (MR) of three is ideal. Nutrients are not generally of great concern with white pine as it performs well even on nutrient poor sites but excels on richer sites. Sugar maple and other shade tolerant species will tend to live in the understorey for quite some time. As older individuals in the overstorey die out the tolerant species will grow into the available space. White ash is another example of such a species and, like sugar maple, prefers a moist, deep nutrient rich soil. However, sugar maple is tolerant of a wider range of site conditions and will, therefore, commonly make up a larger percentage of the stand. White ash will tend to increase in numbers and productivity in sheltered slopes with more available moisture and nutrients, such as on the river terrace (MR 4).

Both white ash and black walnut prefer similar sites and will grow well together. The soils on river terraces, either a kame terrace or an extinct floodplain, are often quite nutrient rich, stemming from annual deposition of sediment from spring flooding or by the downslope movement of soluble nutrients. If the terrace has a northerly or easterly aspect the productivity will probably be less than on a southerly or westerly aspect. Moisture deficits may occur occasionally on a southerly aspect on hot, sunny afternoons. This may not be due to limiting moisture, but rather, the trees inability to take up water fast enough to meet the rate of evapotranspiration. This problem occurs more frequently on drier, southerly facing slopes. Establishment of young trees in these low lying areas can sometimes be difficult as cool air accumulates downslope resulting in frost in late spring after leaf emergence, or early fall before new growth has hardened off.

Along the rivers edge, species tolerant of saturated soil conditions will thrive. These may include silver maple, willow and cedar. Of these three, willow is the only one that prefers these sites. Cedar and silver maple will grow well here but tend to colonize these sites due to reduced competition from more aggressive species. Where floodplains are imperfectly to moderately well drained walnut, ash and other intermediate successional species grow exceptionally well. Riparian forests also tend to be very productive because of the plentiful nutrients and moving groundwater associated with the river.

Moving upslope, a complex of sugar maple, American beech and basswood is not uncommon. The beech and basswood prefer moist conditions and will tend to decline in numbers and quality as the moisture regime becomes drier, from moderately moist (4) at the lower slope to fresh (2) at mid-slope to moderately fresh (1) at the upper slope and crest. Sugar maple will dominate where the moisture regime is 2 - 3. As sugar maple is shade tolerant, it becomes light saturated at relatively low intensities. Its relative performance on easterly, southerly or westerly aspects would be fairly similar, where on hot sunny afternoons a moisture deficit may develop.

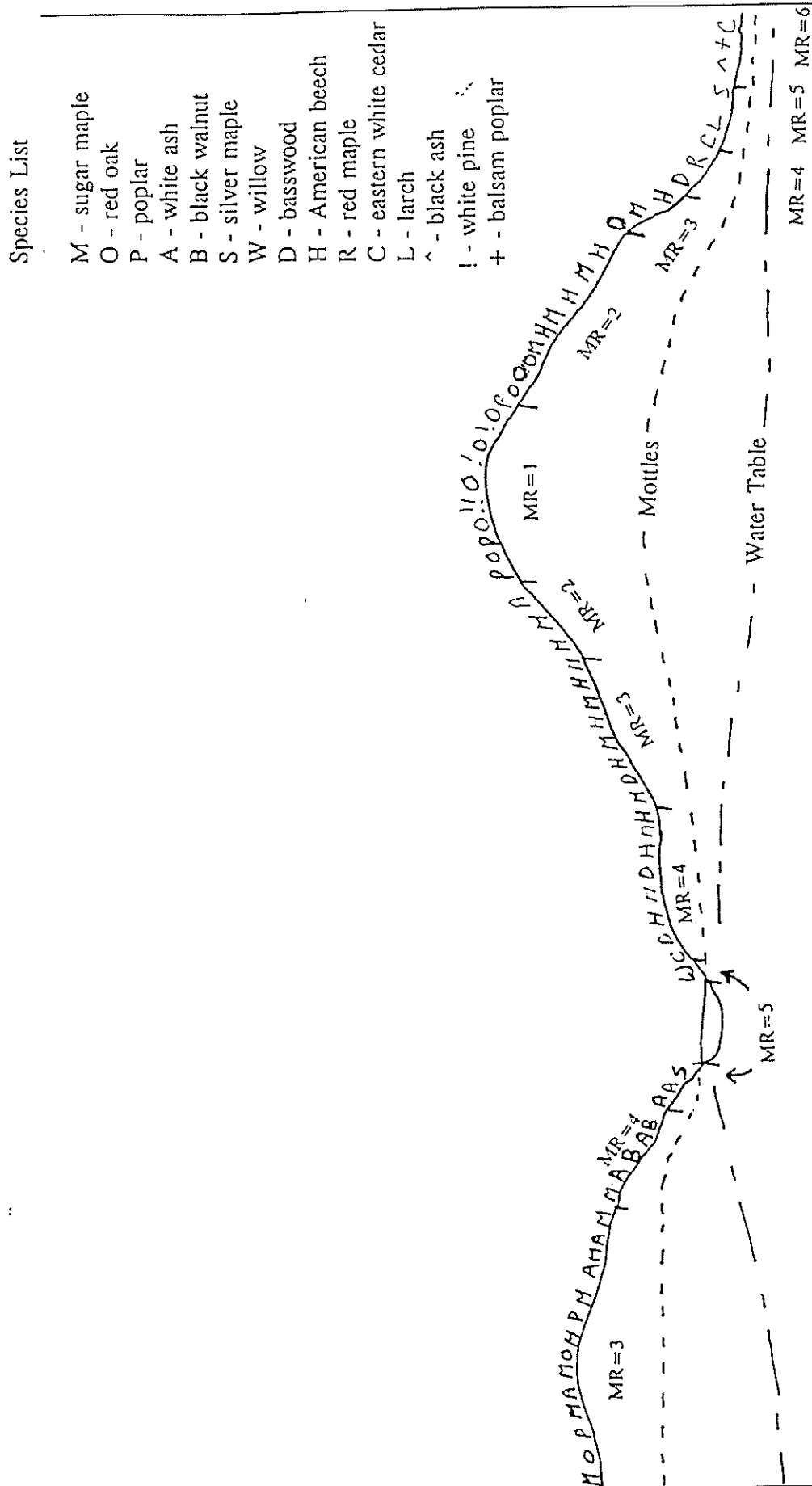


Figure 2. Hypothetical forested landscape in southern Ontario typical of terminal moraines. Figure is not to scale.

At the upper slope and crest the moisture regime is drier (1 - 2) and moisture deficits are more common, regardless of outside temperature. Such sites are typically lower in available nutrients due to leaching and do not accumulate as much moisture due to rapid surface runoff. They are also exposed to other climatic extremes (wind and temperature) than sites on lower, protected slopes. Although these sites will readily support a forest similar to what was described at the beginning, it will typically not be as productive. Because the trees would be regularly stressed, they are more susceptible to disease and insects.

In swampy areas, one can find various mixtures of trees. Many of these wetland forests were once dominated by white elm. Since elm has been largely eliminated as a canopy species, its position has been filled by a number of species. On sites that are more or less saturated all year, cedar is typically dominant. On sites that at least the surface soil dries up to some degree, a wider variety of trees may be found. This may include red and silver maple, balsam poplar, black ash, tamarack and, occasionally, white elm. Although these sites possess large accumulations of nutrients, these nutrients are generally unavailable. Much of the nitrogen, carbon and sulphur are tied up in undecomposed organic matter. Bases, or metals, such as iron, magnesium and manganese, are microbially reduced and cannot be utilized by most trees. Oxygen in the soil rapidly becomes limiting. In spite of all these factors many trees survive, although productivity is generally lower than other site types.

SITE PREFERENCE

Every tree species has a specific set of site conditions under which it grows best. Some species, such as sugar maple and white pine, grow over a range of site conditions. Others, such as red pine and black walnut, have a narrow range. Generally, species will grow best on high quality sites; however, species adapted to poor sites will grow better on a poor site than a species that prefers high-quality sites. Under some circumstances, a species may successfully colonize an area that is not a preferred site. For example, sugar maple is sometimes found on rapidly drained upland sites, which are not preferred by maple. Sugar maple on those sites grow slowly, are of very poor quality and are subject to attack by a range of insect and disease organisms. A red oak on the same site may exhibit good growth and quality. The sugar maple would be said to be growing 'off-site'.

SITE QUALITY

Foresters are constantly looking for ways to estimate the potential of a site for the growth of different tree species. Volume growth is perhaps one of the best indicators of site quality, but it is difficult to measure. Basal area growth is related to site quality, but its relationship to volume is dependent on tree height, and stand density. Height growth is dependent upon site quality so the relationship between height and age is used to determine site index, which is the most common method of estimating site quality.

Site index is developed by measuring the growth of a tree species on a variety of sites. It is commonly given in tables or represented graphically by site index curves. An average site index curve is generated from the height of dominant trees at a specified base age. A base age near the planned rotation age of the trees is usually used, normally 50 years in the east and 75 or 100 years in the west. Younger ages can be used when there are not enough trees of the index age or older in an area. A family of curves with the same shape is generated for site index over the range observed in the field (Fig. 3.3).

Point-intercept is another method that can be used to estimate site quality when only young or juvenile stands are available in an area. The point-intercept method requires the measurement of the height growth of three or five years above breast height (DBH). DBH is generally accepted to be the minimum height at which a tree has surpassed the competition from 'weed' species, and is 'free to grow'. The early growth in the free to grow state has been well correlated to growth potential in a number of coniferous species.

Indices based on height growth have been developed from even aged stands. Height growth of shade tolerant species in uneven aged stands is not a useful indicator of site quality as they often undergo periods of suppression and slow growth in a shaded understorey. Generally such trees cannot be used to accurately determine site index.

Certain plant species have very specific requirements for site. As such, some plants act as phytometers, or indicators, of climatic and soil conditions. This is the underlying premise of the development of site regions and site districts (Hill, 1959). This is the principle behind Forest Ecosystem Classification (FEC) or Ecological Land Classification (ELC). This type of classification system uses both biotic and abiotic site features to classify a site. Essentially, the product of an FEC will allow the forest manager to observe certain vegetational features and make specific inferences about the potential site quality for a variety of tree species.

Conversely, describing the soil can provide the information required to make a good estimate of site potential. Combining the information gained from a complete soil description and indicator species will improve the accuracy of the estimate.

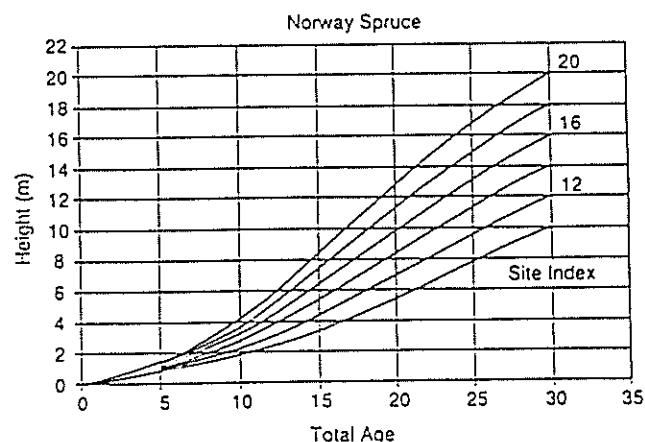
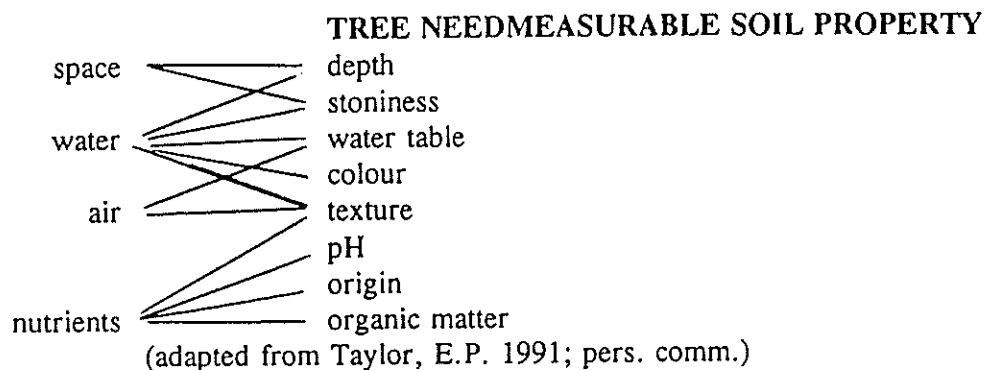


Figure 3.3 Sample site index curves for Norway Spruce (Gordon, et al., 1989).

REVIEW

1. The last glaciation, which ended 10,000 to 12,000 years ago, moulded the landscape, much as we see it now.
2. Wind and water, man and animals, climate and time have all affected the development of soils.
3. Most of the tree species we find in our forests in North America today originated through interactions that took place million of years ago.
4. Most sandy soils, some organic soils and many agriculturally degraded soils are nutrient poor.
5. Macronutrients are those nutrients required in relatively large amounts. These include: hydrogen, oxygen, carbon, nitrogen, potassium, calcium, phosphorus, magnesium and sulphur.
6. Micronutrients are nutrients required in relatively small amounts. These include: iron, manganese, copper, zinc, molybdenum, boron and chlorine.
7. A well-structured soil has a mix of pore sizes and crumbles readily, but not into individual particles (e.g. most loam soils).
8. Geography and climate affect site conditions by influencing temperature, precipitation, length of growing season, amount of solar radiation and exposure to wind.
9. Site indices have been developed to give a rough estimate of how well a given tree species will grow under particular site conditions.

10.



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Chapter 4

TREE GROWTH AND DEVELOPMENT

Sheila Pease¹

Understanding the basics of how trees grow gives some insight into what to expect from a tree crop, and how and why to apply management techniques to achieve the desired characteristics.

PHOTOSYNTHESIS

All life on earth uses chemical energy for all its activities, to grow, to move, to work, or just to survive. The energy must be in a special form in order to be useable. It is the chemical energy that is stored in linking carbon atoms together that is released by living organisms and used for various activities. On earth, the only source of this energy, is the green plant.

Photosynthesis is the process green plants use to convert light energy to chemical energy. For this process to occur efficiently the plant must contain **chlorophyll** to trap sunlight, be porous to take in CO₂ effectively (for building carbon compounds), keep cool in full sunlight, and be able to transport materials quickly. The plant is able to accomplish all of this using leaves.

Plants require a large surface area to volume ratio to maximize the area exposed to light and air for rapid exchange of gases. Broadleaves have a high surface to volume ratio, since they tend to be flat, thin and wide. Conifer leaves have a lower surface to volume ratio, since they tend to be flat, thin and wide. Conifer leaves have a lower surface to volume ratio which is less efficient for photosynthesis, but is more suited to winter conditions.

Because photosynthesis involves many different reactions, many factors can influence the rate at which it is carried out. Conditions are rarely optimal for photosynthesis. Some of these factors such as light, temperature, oxygen concentration, CO₂ concentration, genetics and leaf morphology affect it directly; others such as water status, nutrition and growth rate affect it indirectly. Temperature may affect it both directly and indirectly.

¹ Adapted from Agricultural Botany, Text 340 010, G. Hofstra, Environmental biology, 1989.

Three different parameters of light affect plants - light intensity, light duration and light quality. These parameters affect not only photosynthesis, but also several aspects of plant growth and reproduction. Chlorophyll can only absorb light at certain wavelengths in the visible spectrum. Red and blue wavelengths are most readily absorbed. Green light cannot be used, and is reflected to give leaves their characteristic green colour. Many plants do not grow well under florescent lighting, since the necessary wavelengths are not provided.

As days get shorter and nights get colder in the fall, the tree gradually cuts off the flow of sugars and nutrients to the leaves. This causes photosynthesis to shut down and chlorophyll to break down. The bright yellows, oranges and reds associated with autumn leaves are the colours of other chemicals associated with photosynthesis, which were masked by the green chlorophyll. Once the leaf is dead it falls off leaving a distinctive leaf scar below the bud for next year.

SHADE TOLERANCE

Shade tolerance is the ability of trees to develop and grow in the shade of other trees. Trees can range from very tolerant, implying they can survive and develop in shade, to very intolerant, implying they cannot exist in the shade of other individuals. Table 4.1 lists the relative tolerance of tree species found in Ontario.

The rate of photosynthesis in intolerant species increases with increasing light intensity up to full sunlight. However, they cannot efficiently photosynthesize at low light intensity. Tolerant species are photosynthetically efficient at low levels of illumination, but have a maximum photosynthetic rate at a much lower light intensity than intolerant species. Even though tolerant tree species become saturated with light at relatively low levels, most will grow better in full sunlight if other factors remain equal.

Tolerance must be considered when choosing a tree species for a particular site or choosing a site for a particular tree. For example, it would be inadvisable to attempt to plant red pine in a young stand of sugar maple and beech, since red pine cannot survive in the shade of hardwoods, and would gradually die out. Similarly, an understanding of tolerance can help with the management of an existing stand by providing knowledge of the type of regeneration to expect in the understorey and in disturbed areas.

PRIMARY GROWTH

Growth involves three processes: cell division, cell expansion and cell differentiation. All of these go on simultaneously, but are spatially separated into zones along the root and shoot, with one zone blending into the next.

The plant is composed of hundreds of thousands of cells, but each originated in two small areas of the germinating seed: one at the tip of the root (Fig. 4.1) and one at the tip of the shoot (Fig. 4.2). These areas where cells divide are called **apical meristems** because they are located

Table 4.1: Shade Tolerance of Native Eastern Canadian Trees and Important Exotic Agroforestry Species Grown in Ontario

Very Tolerant		Intolerant	
<u>Conifer</u>		<u>Conifer</u>	
Eastern hemlock	<i>Tsuga canadensis</i>	Eastern red cedar	<i>Juniperus virginiana</i>
<u>Broad-leaved</u>		Jack pine	<i>Pinus banksiana</i>
American Beech	<i>Fagus grandifolia</i>	Pitch pine	<i>Pinus rigida</i>
Big shellbark hickory	<i>Carya laciniata</i>	Red pine	<i>Pinus resinosa</i>
Blue beech	<i>Carpinus caroliniana</i>	Scots pine	<i>Pinus sylvestris</i>
Flowering dogwood	<i>Cornus florida</i>	<u>Broad-leaved</u>	
Mountain maple	<i>Acer spicatum</i>	Black ash	<i>Fraxinus nigra</i>
Striped maple	<i>Acer pensylvanicum</i>	Black cherry	<i>Prunus serotina</i>
Sugar maple	<i>Acer saccharum</i>	Black walnut	<i>Juglans nigra</i> L.
		Bitternut hickory	<i>Carya cordiformis</i>
		Butternut	<i>Juglans cinerea</i> L.
<u>Conifer</u>		Chinquapin oak	<i>Quercus muehlenbergii</i>
*Balsam fir	<i>Abies balsamea</i>	Honey-locust	<i>Gleditsia triacanthos</i>
Black spruce	<i>Picea mariana</i>	Kentucky coffee-tree	<i>Gymnocladus dioica</i>
*Eastern White Cedar	<i>Thuja occidentalis</i>	Mockernut hickory	<i>Carya tomentosa</i>
Red spruce	<i>Picea rubens</i>	Pecan	<i>Carya illinoensis</i>
<u>Broad-leaved</u>		Sassafras	<i>Sassafras albidum</i>
Basswood	<i>Tilia americana</i>	Speckled alder	<i>Alnus rugosa</i>
Black gum	<i>Nyssa sylvatica</i>	Tulip-tree	<i>Liriodendron tulipifera</i>
*Black maple	<i>Acer nigrum</i>	White ash	<i>Fraxinus americana</i>
Hop-hornbeam	<i>Ostrya virginiana</i>	White birch	<i>Betula papyrifera</i>
Manitoba maple	<i>Acer negundo</i>		
Red/Green ash	<i>Fraxinus pennsylvanica</i>		
Red maple	<i>Acer rubrum</i>		
Red mulberry	<i>Morus rubra</i>		
Silver maple	<i>Acer saccharinum</i>		
Slippery elm	<i>Ulmus rubra</i>		
Tolerant		Very Intolerant	
<u>Conifer</u>		<u>Conifer</u>	
Eastern white pine	<i>Pinus strobus</i>	Tamarack	<i>Larix laricina</i>
Norway spruce	<i>Picea abies</i>	<u>Broad-leaved</u>	
White spruce	<i>Picea glauca</i>	Balsam poplar	<i>Populus balsamifera</i>
<u>Broad-leaved</u>		Black locust	<i>Robinia pseudoacacia</i>
Black oak	<i>Quercus velutina</i>	Eastern Cottonwood	<i>Populus deltoides</i>
Bur oak	<i>Quercus macrocarpa</i>	Large-tooth aspen	<i>Populus grandidentata</i>
Chestnut	<i>Castanea dentata</i>	Pin cherry	<i>Prunus pensylvanica</i>
Hackberry	<i>Celtis occidentalis</i>	Trembling aspen	<i>Populus tremuloides</i>
Pignut hickory	<i>Carya glabra</i>	Willows	<i>Salix</i> spp.
Red oak	<i>Quercus rubra</i>		
Rock elm	<i>Ulmus thomasi</i>		

* Shade tolerance varies

at the end, or apex of the root and shoot. The apical meristems consist of a tiny region up to about 2 mm (1/16 ") in length that is made up of small cubical cells. The cells duplicate all the material within them every time they divide.

The region behind the apical meristem has been called the **zone of elongation**. The new cells left behind here by the dividing cells begin to change in several ways, including size. Although the cells may become somewhat wider, they increase in length up to 10 or 20 fold. The elongation of the cells also causes the meristems to be pushed away from the older part of the plant. Cell elongation contributes to most of the height of the plant and the length of the roots. In the case of the roots the meristem is actually pushed through the soil by the elongating cells. The root meristem is covered by a **root cap** that offers protection as the meristem is pushed through the soil. The **shoot meristem** does not need such protection, but must give rise to cells that will produce the stem, leaves, branch buds and flowers. These young developing leaves cover the growing tip and protect it. In the crotch of the leaves some meristematic tissue is left behind to form the buds, shoots or branches. The zone of elongation is the only area in which cells increase in size, so that, in the case of the root, only the root cap and apical meristem in the root are being pushed through the soil, and in the case of the shoot, only the apical meristem gets pushed higher. This explains why tree branches can grow longer, but they do not get higher from the ground as the tree grows.

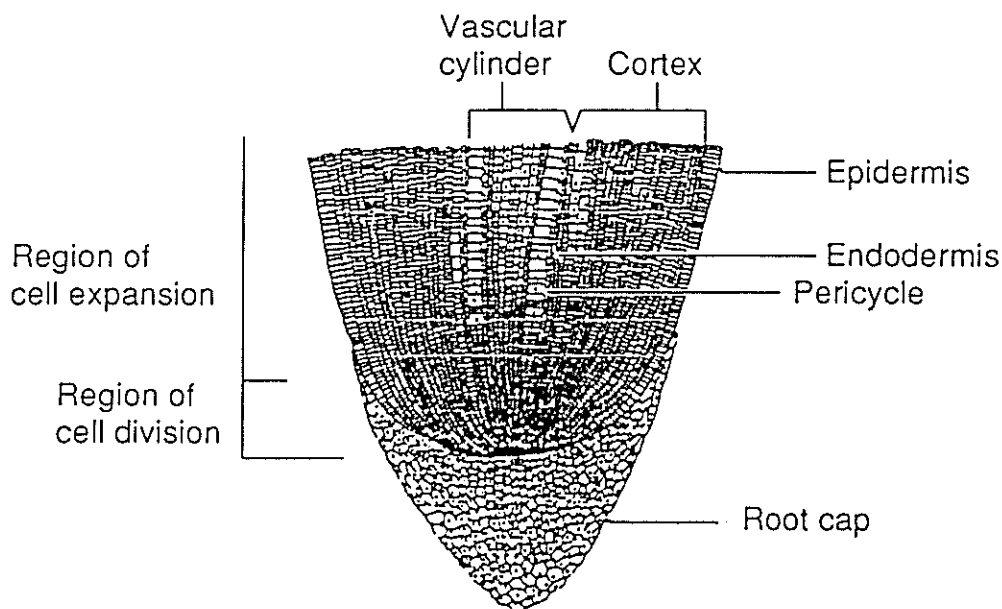


Figure 4.1. A longitudinal section through a root tip (Hofstra, 1989)

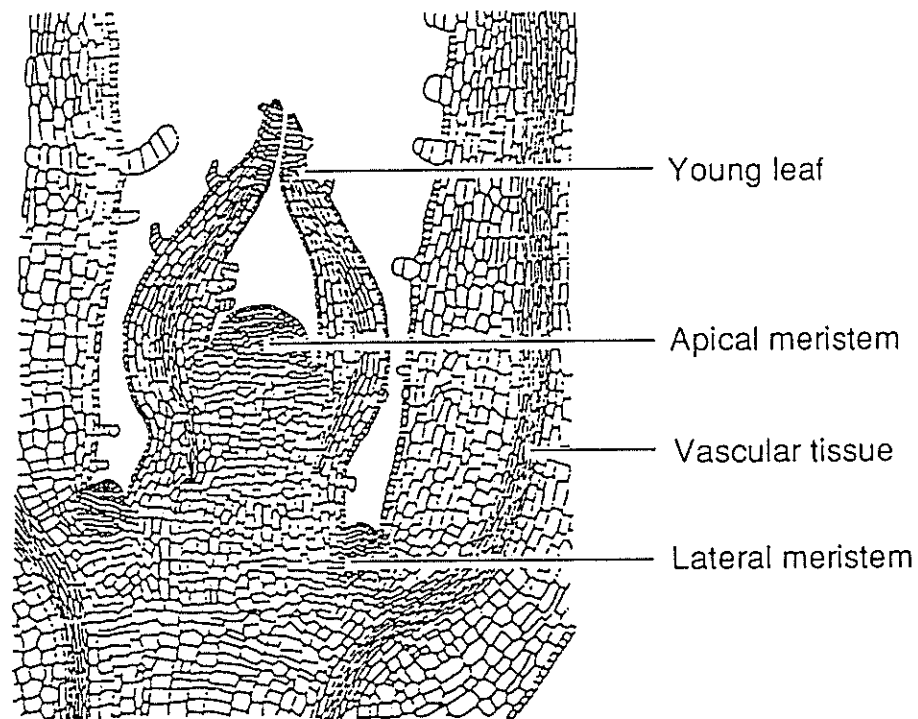


Figure 4.2. A longitudinal section through a shoot apex (Hofstra, 1989)

CELL DIFFERENTIATION

Up until this point most of the cells have been much alike, but once elongation slows down, the cells begin to change to take on specific functions. Several different types of tissue develop that can be found throughout the plant. The outermost layer of cells forms the **epidermis** or skin on the plant. Beneath the epidermis is usually a layer of cells that are irregular in shape, thin walled and often store starch. This layer is called the **cortex**. Beneath the cortex lies the vascular, or transport system of the tree, which is responsible for moving water, minerals and other substances from the roots to the shoot and for moving sugars from the leaves to other parts of the plant. The **xylem** tissue, composed of dead thick walled cells, transports water and minerals through the plant, while the **phloem**, composed of small living cells, transports sugars. Inside the transport tissue, at the centre of the tree may be a **pith**, composed of large, thin-walled cells (Fig. 4.4).

BRANCHING

In trees the shoot meristem growth forms a bud containing leaves and possibly flowers. However, in most cases they do not develop in the year that they are formed, but remain dormant through the first winter. These buds are usually covered with bud scales that prevent injury and desiccation of the bud. They are produced at the base of leaves from meristematic tissue left behind by the apical meristem. Thus, new buds are normally only produced on the current year's growth. Leaves appear only from the buds formed the previous summer.

COPPICE

Coppice growth refers to stock grown from sprout origin. Most hardwoods and some conifers produce such sprouts. There are 3 basic types of coppicing: stump sprouts, stool shoots, and root suckers (Fig. 4.3).

Stump sprouts Stump sprouts develop from dormant buds in the tree trunk. Seedling sprouts are a form of stump sprouts that develop from well established seedlings that have been damaged by browsing, logging, environmental changes, or any number of other things. These coppiced seedlings usually have good form and demonstrate exceptionally fast shoot growth due to the well established root system. Farther up the trunk of older trees, these buds may break dormancy as a result of some form of stress (e.g. salt stress in roadside trees) and form epicormic branches. Such branches may also grow on trees in a stand that has been heavily thinned.

Stool shoots Stool shoots develop from exposed cortex buds and phloem when a tree is cut down, or a branch is removed. This is the least desirable form of coppicing because the new shoot is weak and subject to decay where it is attached to the old stump.

Root suckers Root suckers develop from dormant, or adventitious buds on roots. Some of the few species which commonly develop root suckers are aspen, American beech, and black locust.

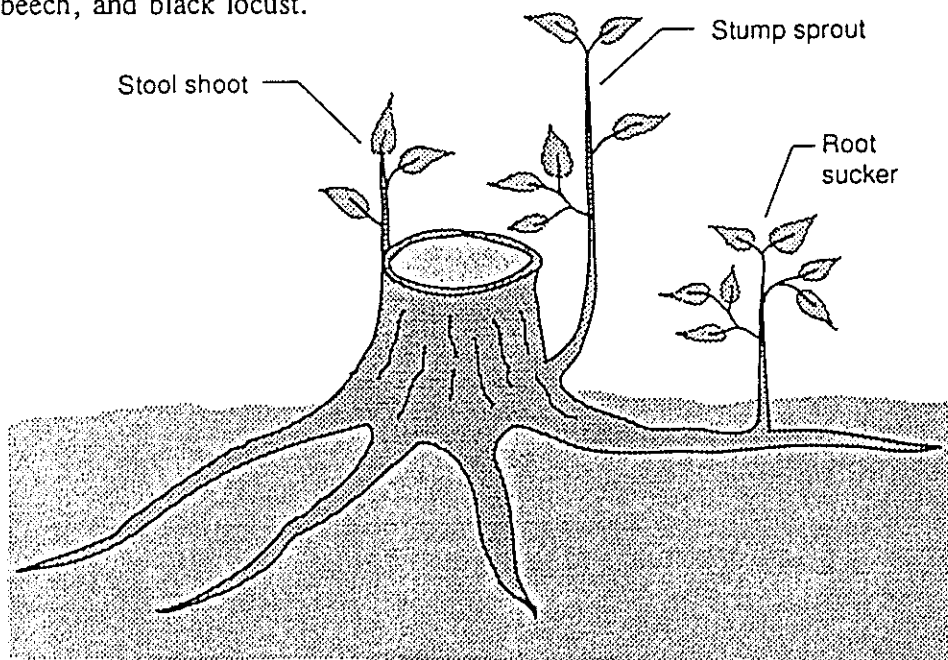


Figure 4.3. Three types of sprouts which contribute to forest tree reproduction (Berglund, 1976)

Coppicing is the basis of short-rotation energy plantations for biomass production. In these plantations coppice growth is harvested every 3 to 10 years and chipped and burned directly or

processed to produce fuel like ethanol. The number and longevity of sprouts depends on the size of the stump; larger stumps produce fewer and less desirable sprouts. These trees continue to coppice for several rotations, after which time they are replaced with new stock.

Coppicing is also an important form of regeneration in forests. For most timber crops, seed origin trees are preferred to coppice growth for several reasons:

1. Coppice growth frequently has a higher occurrence of defect since the dead tissue of the old stump provides easy access for many of the wood-rotting fungi.
2. Stem form of coppice growth (with the exception of seedling stump sprouts) is often inferior to that of trees grown from seed, although in some cases there appears to be no difference after a period of time.
3. The vigour of coppice growth, other than seedling stump sprouts, may be maintained for a shorter period of time than that of trees grown from seed.

However, coppice regeneration is usually more reliable than seedlings, especially for trees, like oaks, that have infrequent seed crops. They are also important in maintaining the genetic base of the forest as the coppice-origin trees are genetically identical to their parent. Vigorous coppice growth may outgrow browsing pressure from wildlife (e.g. deer) better than seedlings.

SECONDARY GROWTH

Leaves, fruit, seeds, stems, buds, flowers and roots are produced through primary growth. Secondary growth in trees produces wood. Secondary growth is the increase in diameter of stems, roots or branches that results from the activity of the **vascular cambium** and to a lesser extent the **cork cambium** (Fig. 4.4).

VASCULAR CAMBIUM

Vascular cambium is the layer of meristematic tissue between the xylem and phloem that has retained the ability to divide. Towards the inside the cambium produces a new layer of xylem, while on towards the outside it produces a new layer of phloem. It is a thin layer of small thin walled cells. They are capable of dividing along the radius of the stem and also at right angles to the radius. It is called **vascular cambium** because it lies within the vascular tissue and produces more of it.

While the vascular cambium begins its activity and the stem begins to increase in diameter, one of the cell layers in the outer cortex also begins to divide. This meristematic layer is called the **cork cambium** because it gives rise to cork cells. The cork cells eventually form most of the bark on the outside of the tree. The cork cambium does not form a uniform ring around the stem, but rather is discontinuous. Its even and irregular location eventually gives bark its characteristic appearance.

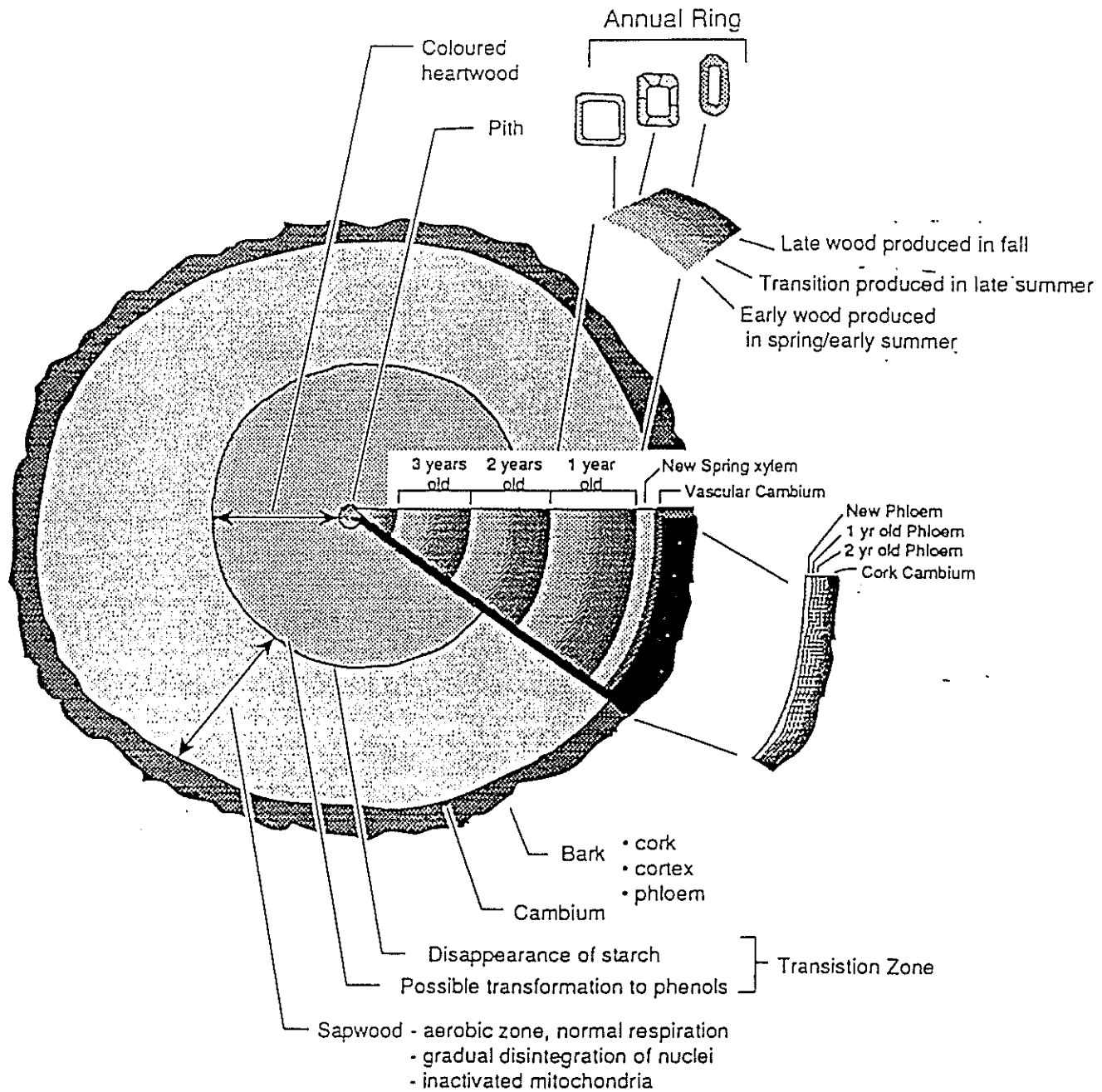


Figure 4.4 Cross section of a tree stem showing physiological characteristics.

SUMMER GROWTH PATTERNS

At the end of a growing season buds form at the apex and ends of branches. As described, the buds expand and break early the following spring, followed by elongation, differentiation, and then bud formation. Generally, root growth begins earlier and continues longer than terminal growth. Diameter growth also continues longer than terminal growth. Genetics, local site

conditions, latitude, and weather combine to determine the length of the growing season. There are 3 ways that terminal growth occurs: predetermined, continuous, and episodic.

Predetermined growth In the case of trees such as red pine, growing conditions of both the current and previous year affect terminal growth. The previous year determines the number of needles and flowers, and the current year determines the extent of elongation. Buds formed during the summer contain all the needles and flowers that will grow the following season. If the following growing season is good, elongation will be high and the needles will be spaced far apart. If the following growing season is poor, the same number of needles will be bunched close together. Since only one whorl of branches is formed annually, the age of a tree may be determined by counting the whorls as long as they are well defined (Figure 4.5).

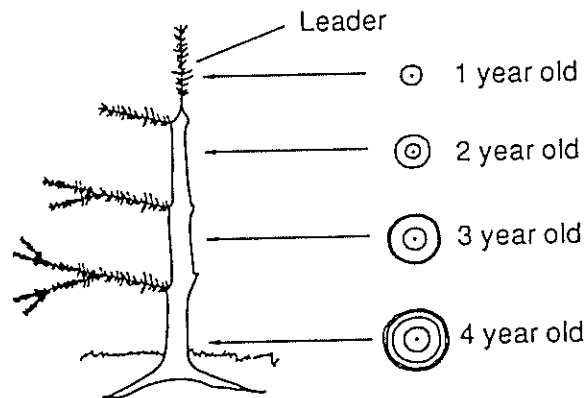


Figure 4.5 Predetermined growth, aging a conifer tree.

Continuous growth In some trees, such as walnut and poplar, the number of leaves is not predetermined. Elongation occurs, leaves expand, and buds are set late in the summer. Once buds are set height growth has ended for the year. Genetics and growing conditions in the current summer determine the amount of terminal growth and the number of leaves produced in a given season.

Episodic growth Some trees such as oaks will grow, set bud, and if growing conditions are good, break bud and grow again before setting bud for the following summer. If a growing season is particularly good, an oak may flush as many as 3 times.

THE STRUCTURE OF WOOD

SAPWOOD AND HEARTWOOD

When the trunk of a tree is cut across, the centre wood usually appears darker than the wood towards the outside. The outer rings, which are lighter in colour are the **sapwood** and contain rays made up of living cells. Water and minerals are carried in the xylem of the sapwood. The darker wood in the centre, called the **heartwood**, consists of old inactive xylem cells which now function as storage. These cells are heavily infiltrated with oils, gums, resins and tannins. The proportion of sapwood to heartwood and the difference in colour between them varies greatly from species to species. For example, black walnut has extremely dark and valuable heartwood, with moderately light coloured sapwood. American basswood has light coloured heartwood that is hard to distinguish from its sapwood.

ANNUAL RINGS

In the spring and early summer conditions are ideal for growth. During this time the cells that are produced by the vascular cambium are large and appear light in colour. As the season progresses the tree frequently is under moisture stress and the cells become smaller and their thicker cell walls make them appear darker in colour. At the end of the season stem growth stops all together. The following spring growth resumes with large cells creating a sharp line visible between the small cells from the previous fall and the large cells produced in the spring. The layer of large cells and the smaller cells comprise one season's growth and together are called an **annual ring** (Figure 4.4). Annual rings form the wood grain patterns in cut wood, but only appear as rings when looking at a cross-section.

The number of annual rings at the base of a tree reveals the age of the tree. In some trees these rings are easily counted when the difference between spring and summer wood is distinct. In other trees, rings are more difficult to count, especially if there is no colour difference between spring and summer wood, or if the rings are very close together. The degree of difference in colour between annual rings varies with the tree species. The width of the annual ring can vary considerably from year to year and reflects both the species and the growing conditions. Some species such as black locust grow very quickly, and therefore, have wide rings, while other species such as sugar maple are slow growing and produce narrow rings. Various stresses, such as: drought, disease, competition or insect defoliation can result in very thin rings. Ideal growing conditions produce wide rings. In this way a history of the growing conditions and the climate are preserved in trees.

HARDWOOD AND SOFTWOOD

The hardwoods are broadleafed trees and the softwoods are conifer trees. The terms hardwood and softwood do not accurately describe the hardness or density of the wood. Some hardwoods such as balsa wood can be very soft, whereas some softwoods such as hemlock are very hard.

The structure of conifer wood is relatively simple (Fig. 4.6). The wood is mostly made up of long tapering tracheids which tend to line up in rows. Only conifer wood contains resin ducts, which carry resin from the cells lining them. When a conifer tree is wounded the resin oozes out, apparently protecting the tree from decay-producing fungi and bark beetles.

In comparison the structure of hardwoods is more complex, owing to the greater diversity of cells. Although wood is composed largely of dead xylem cells, not all the cells in the trunk are dead. Groups of living cells called rays, occur at regular intervals in the trunk and run along the radius. The rays tend to be much larger in hardwoods than conifers, and can make up a considerable proportion of the wood. They are produced by the vascular cambium and form a continuous bundle from the cambium inward. The size of the rays varies with the tree species and can be used as an identification feature of wood. Sugars are transported into the rays, where they are converted to starch for storage.

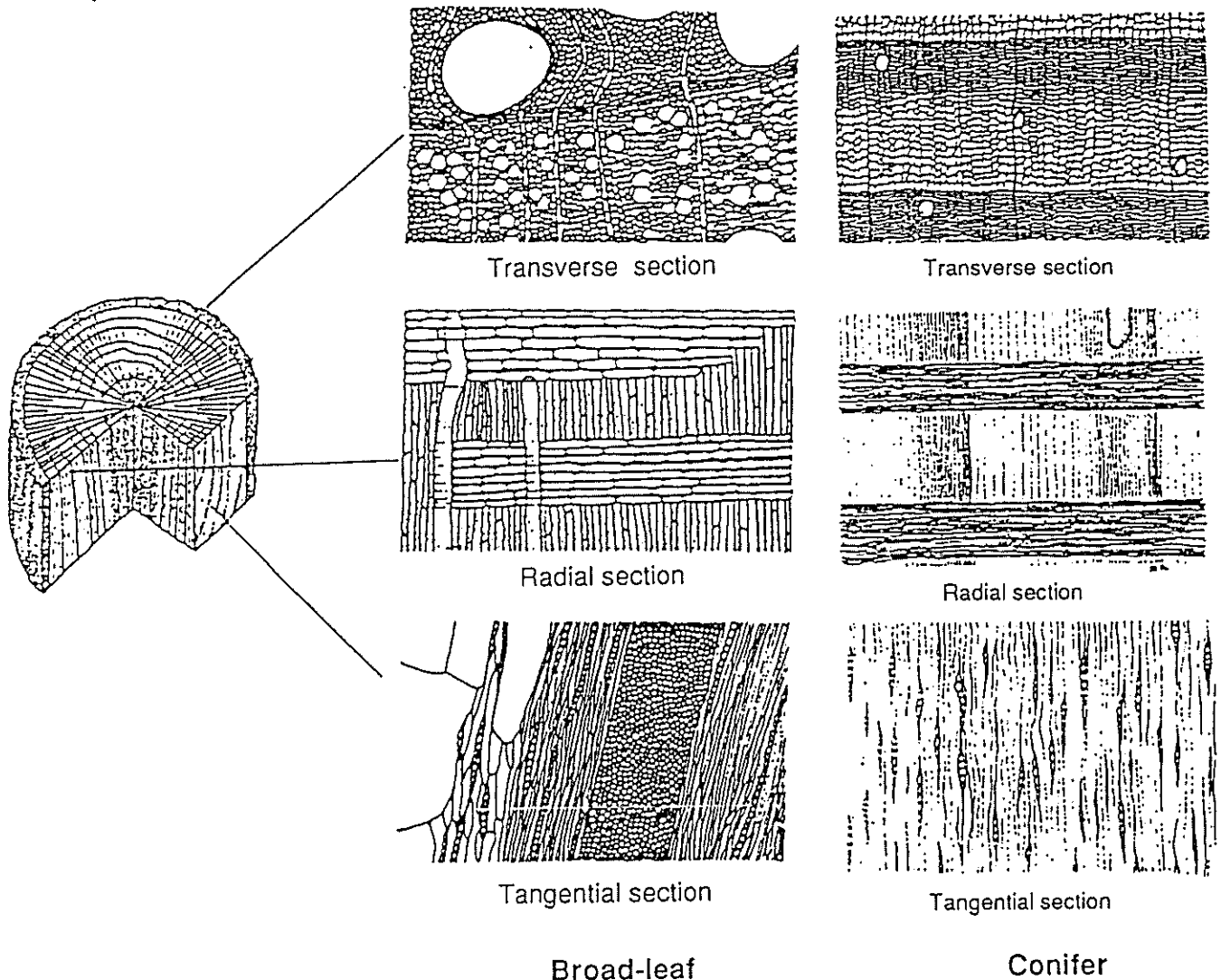


Figure 4.6 Sections through broad-leaf and conifer wood showing the diversity of cells, rays and vessels (Hofstra, 1989).

PATTERNS IN WOOD

WOOD GRAIN

Wood can display many beautiful patterns when cut into boards or veneer. The species from which the wood came can usually be identified by its pattern. The most noticeable aspect of the pattern is due to the colour differences between spring and summer wood. Trees that have distinct annual rings in cross-section form the most distinct patterns.

The most attractive and unusual patterns in wood are shown when a log has been cut tangentially (at right angles to the radius). In a tangential cut the rings appear very wide (Fig. 4.7). The spring and summer wood shows as large areas of lighter coloured wood which are separated by narrower areas of late summer wood. The rays which are cut across in a tangential section add to the diversity of the pattern. The size and shape of rays varies from species to species, but usually they show as elongated darker areas on the light areas of wood. Because wood cut at a tangent is in much greater demand, much of the wood from high quality, high value trees is cut as veneer. Veneer is cut by rolling a log into a knife so that a thin, continuous sheet is cut, always at exact right angles to the radius.

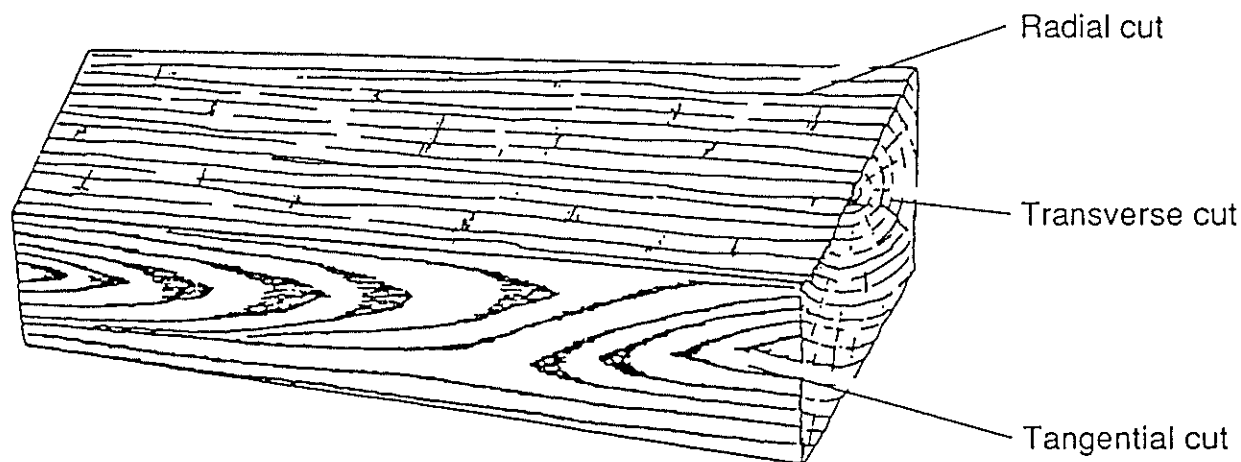


Figure 4.7 Wood patterns associated with direction of cut

KNOTS

Branches arise from buds formed on new growth, and therefore connect close to the centre of the tree. As the tree and branch grow in diameter they do so together and the wood is intertwined. The area where the branch is connected to the tree is called a knot. Knots are usually not seen in veneer or plywood, but are common in construction lumber. The wood in knots is often harder than the surrounding wood. If a knot is tight it will not weaken the wood. A

tight knot is formed when the trunk and branch are both alive and growing together (Fig. 4.8a). Such a knot does not become loose on drying and does not fall out. If a branch dies, it no longer grows with the tree trunk. As the trunk continues to grow it now grows over top of a dead branch and the wood of the trunk is no longer intertwined with that of the branch (Fig. 4.8b). A board cut from this part of the trunk will have loose knots. As the wood dries the knot shrinks, becomes loose and may fall out.

Boards cut from a tree that has been pruned and has grown over the wound will have knots in the wood grown before pruning, but will be clear in the wood laid down after pruning (Fig. 4.8c). Pruning is important to managers of high value timber because clear wood has higher market value than wood with knots.

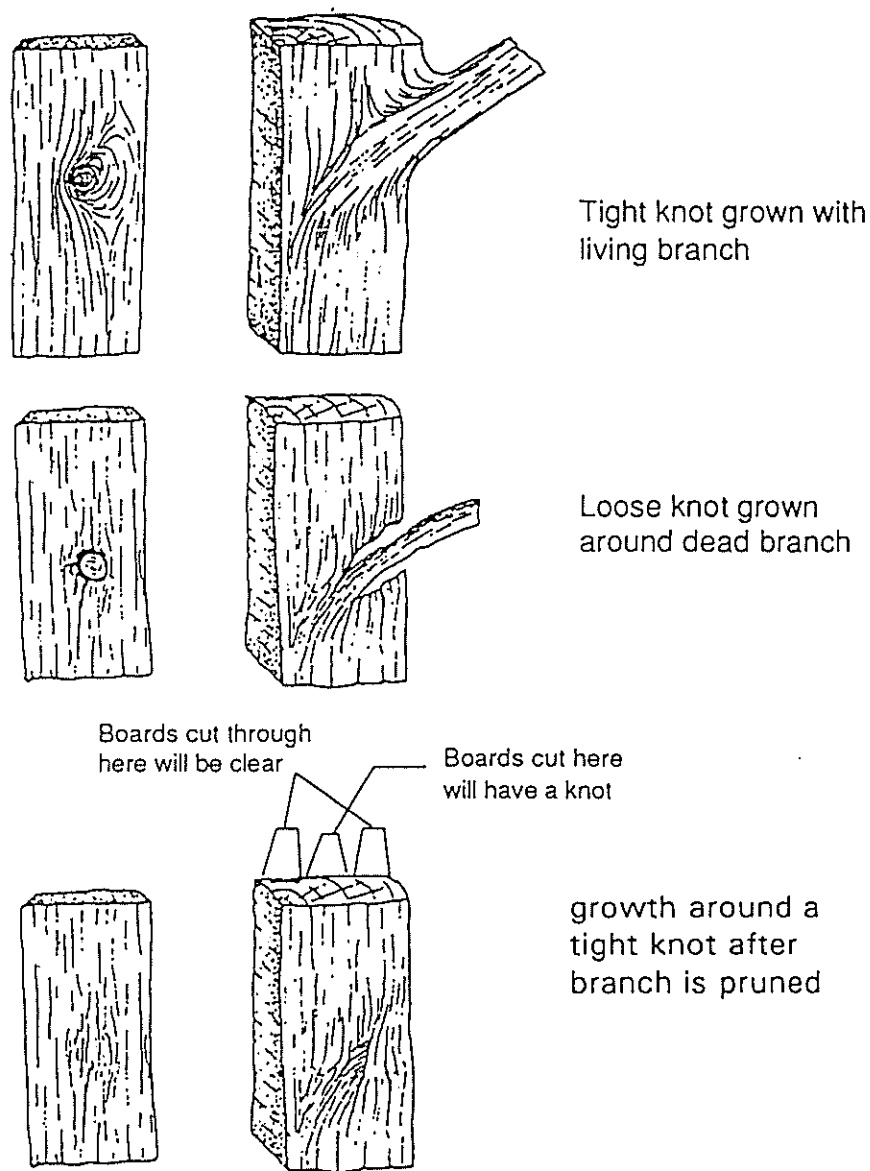


Figure 4.8 Tight, loose and pruned knots in wood.

REVIEW

1. **Primary growth**, from seed to seedling, involves cell division, expansion and differentiation. All primary growth is initiated from **apical meristems**. After initial cell division some cells begin to differentiate, each taking on special functions within the plant.
2. **Secondary growth** increases the thickness of stems, branches and roots, and in trees produces wood.
3. **Annual growth rings** are caused by differing rates of tree growth during the spring and winter seasons.
4. **Sapwood** is the active xylem, lighter coloured, outer part of the tree. **Heartwood** is the (usually) darker coloured, inner portion of the trunk or branch.
5. **Wood grain** patterns are caused by distinct annual rings and **rays**.
6. **Shade tolerance** is the ability of a tree to grow and develop in the shade of other trees. Tolerance is an important factor in deciding upon the suitability of a particular tree for a particular site.
7. Understanding how trees grow gives some insight into what to expect from a tree crop and how and why to apply management techniques.

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Chapter 5

FOREST STAND GROWTH AND DEVELOPMENT

Peter Williams¹

An understanding of forest growth and development is essential to property owners who use their woodlots for recreation, producing wood products or the promotion of wildlife habitat. Woodlots are often small, yet retain many of the characteristics of larger forest ecosystems. The diversity of plants and animals within a woodlot forms a community of complex interactions which change and evolve over time. Competition and succession are the primary factors affecting the development of plant communities. A silviculturalist manages the community so that competition and succession will develop in a certain direction. When forest management principles are applied to a woodlot, landowners can optimize benefits, depending upon management objectives.

FOREST STAND DYNAMICS

THE FOREST ECOSYSTEM

The **forest ecosystem** is comprised of all interacting tree species, shrubs, herbaceous plants, large animals, small animals and microorganisms that occupy a given forested area, plus their physical environment. Each component of the forest is directly or indirectly related to all others within the association. For instance, windstorms or harvesting that remove certain trees increase light, lessen transpiration and competition, increase growth of the remaining individuals and available growing space on the forest floor, and affect the activities of associated soil biota, insects, birds and mammals.

The **forest stand** is distinct from the forest ecosystem in that a stand refers to only the trees; the forest ecosystem refers to the trees and their integration with their environment. A stand is defined by the Society of American Foresters (1958) as "an aggregate of trees occupying a specific area and sufficiently uniform in species composition, age arrangement and condition as to be distinguishable from the forest on adjacent areas". In a managerial sense, a group of stands administered as an integrated unit is a **forest**.

¹ Except where otherwise noted, this chapter has been adapted from Berglund (1976).

An understanding of **forest stand dynamics**, (the developmental patterns and structural changes of forests), is fundamental to the forester's ability to manipulate the stand in order to promote the desired objective. Developmental patterns vary with soils, climate, disturbance types, species characteristics and time, but seem to follow general trends. Historically this has been referred to as **forest succession**, since in some cases one group of species modifies the environment in ways that allow another group to outcompete it and thus succeed it.

SUCCESSION

Succession is the directional change in vegetation resulting from the interactions among the living (biotic) and the non-living (abiotic) factors of the environment. One plant community gradually replaces another until a state of dynamic equilibrium is reached in what is called the **climax community**. From a classical perspective, succession begins after major ecological disturbances such as fire, disease, an insect infestation or weather (i.e., snow, ice, lightning) destroys existing ecosystems and creates openings where life can begin anew. A gradual and complex series of change (both biotic and abiotic) must occur to re-establish the forest.

Pioneering species, those plant species that come in immediately after a disturbance, germinate, grow, and reproduce to successfully inhabit the vacant ecological **niche**. As the plants increase in size and number, competition and environmental change begin to modify the ecosystem. A new series of plants germinates, grows and reproduces to repeat the cycle of change. In this manner, each group of species facilitates the establishment of the next group. The rate of change becomes more gradual with time until there appears to be no change and the climax community is reached. It should be emphasized however, that communities at every stage in plant succession are characterized not by stability, but by constant change. At any time in the series of change from the beginning to the climax, a new disturbance may interrupt the series and create a new beginning. However, the climax community should continue indefinitely in the absence of disasters or climatic changes because individuals lost from the climax community are replaced by the progeny of that community.

A forest that will maintain itself on a specific site is called a **climax forest**. In the absence of disturbance it will be made up of a combination of tree species which can grow and develop from seedling to mature tree without competition for light or nutrients significantly affecting development. Such a forest is generally capable of perpetuating itself as young seedlings can grow in the shade of the parent. In the Great Lakes-St. Lawrence forest region in Ontario hard maple, beech, hemlock and red spruce all form climax associations, as does black spruce in other parts of the province.

The succession of plant communities is made in response to changes in the physical site generally resulting from the influence of the organisms themselves on the site. Changes brought about by plants may be as subtle as small temperature changes at the soil surface, or they may be as direct as the deposition of organic material which inhibits the development of their own progeny or that of competitors within the existing community.

There are two major forms of succession: **primary succession** and **secondary succession**. Primary succession begins with soil building, on bare areas that did not previously support

vegetation growth. These may be areas of water, sand, or rock. Soils develop from primitive plants, called colonizers, reacting with rock over long periods of time to eventually provide pockets of soil that eventually support larger vegetation. With the accumulation of soil, new plants germinate, grow and reproduce to begin the stages of a new succession.

Secondary succession occurs in areas with well developed soil that were previously vegetated, but which have been altered by such external forces as fire, geomorphic processes, logging or agriculture.

The entire successional sequence may be broken down into discrete parts which makes it easier to classify forest communities as to the place in the successional sequence on a site. Figure 5.1 illustrates natural succession in southern Ontario from an old field to an old forest.

Good Forest management uses the principles of succession and species characteristics (silvics) to encourage the stand development towards desired forest structures and habitats. Successional pathways vary for different site conditions (i.e., soil moisture and chemistry, climate), and when an forest opening is created the new/younger trees have the opportunity to develop. The trees and other plants that develop after a disturbance depend on the existing plants, regeneration that develops from sprouts, planting or seeds from the current or earlier years, the size of the opening and wildlife (e.g., deer browsing some or all plants, squirrels planting seeds).

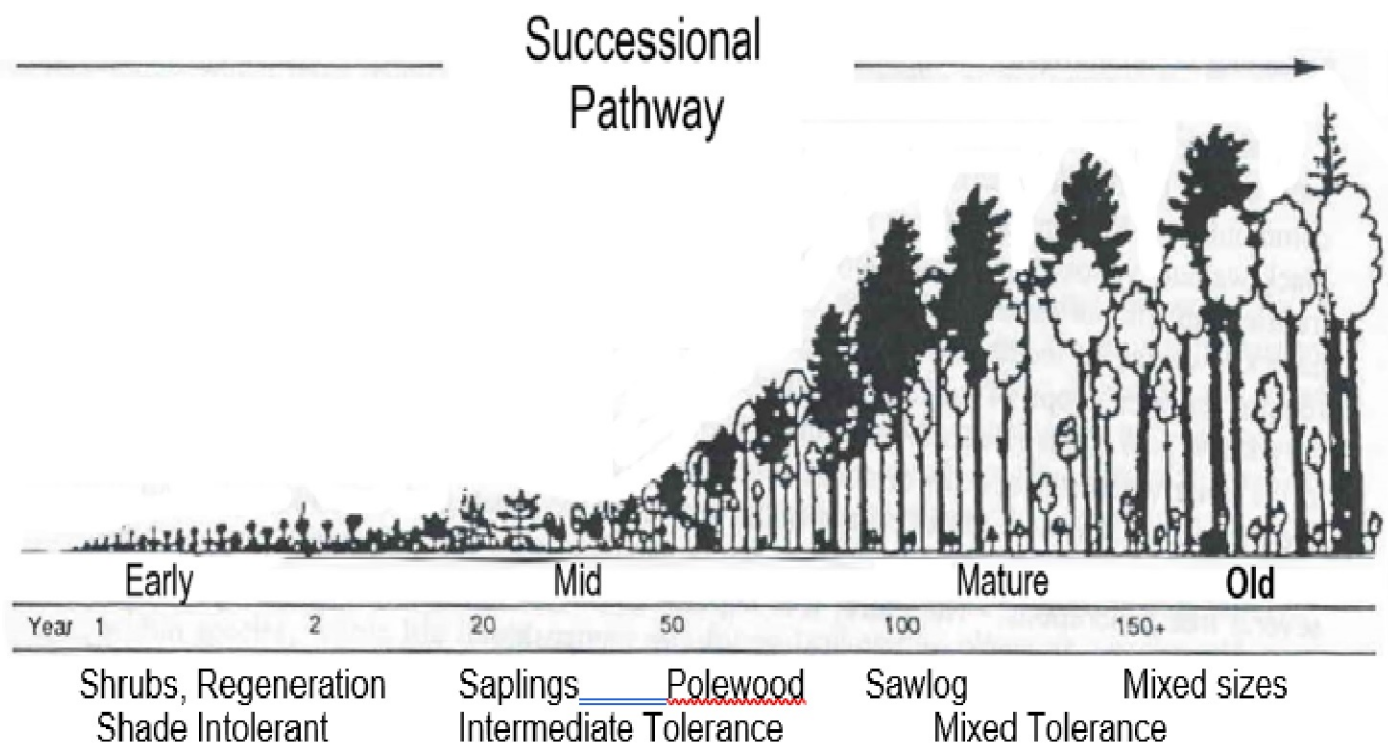


Figure 5.1. Forest Successional Pathway from field or clearcut to old-growth Forest

Among trees, the pioneer stage consists of the shade-intolerant, short-lived, rapidly growing species which invade an area following a relatively severe disturbance. The subclimax stages usually consist of somewhat long-lived species which are intermediate in their tolerance to shade and are relatively fast growing. The climax forest community consists primarily of long-lived, shade tolerant, and relatively slow growing species.

The dominant species of the climax or advanced subclimax communities cannot serve as pioneers because their tolerances to the extremes of site variables, coupled with their rather strict requirements for specific conditions, prohibit their successful early establishment. Similarly, pioneer or subclimax species cannot successfully reinvade and become established in the climax community. The climax species utilize the available resources much more efficiently and are therefore at an advantage in the competitive relationship. In addition, the tolerances of the subclimax species are frequently exceeded in the climax ecosystem, particularly the tolerance to shade. Climax species can exist on the same land area following succession despite the fact that they could not pioneer that area because of the improvement and preparation of the site by preceding communities.

With regard to timber management as one use of forested land, it is interesting to note that most of the more valuable commercial species tend to be members of pioneering or subclimax communities. Examples of these species are white pine, white ash, white birch, black cherry, black walnut, yellow birch and many others. Therefore, since these valuable species occur in the transient subclimax communities, the forester must be concerned with successional trends and have knowledge of methods influencing them. In other words, if the goals of management require repeated crops of subclimax species for one of a variety of reasons, the forester must not only know how to stop succession at the end of each rotation, but also how to reverse succession to the point where the species of concern is most effectively regenerated. Obviously, if too little is done, succession will advance beyond this point. If too much is done, succession will start over and the site may be lost as a part of the productive forest for at least one and, perhaps, several tree generations. Therefore, it is important to know precisely the severity of disturbance required to regenerate a stand with a given species composition.

Cultural practices such as pruning, salvage cuttings and cleanings rarely affect the progress of the successional sequence because they are not catastrophic in the sense that the community is not drastically disturbed. On the other hand, thinnings in stands of subclimax species, particularly those approaching maturity, frequently accelerate succession. These thinnings create openings in the canopy which may be quickly filled in by young seedlings of a variety of species. As the crowns and root systems of the remaining overstory trees encroach into the openings created by the thinning, the resources available to these invaders diminish and only those species tolerant of these conditions; *ie.*, the successional more advanced species, survive in the understory. Where these successional advanced species are undesirable compared to the overstory species, considerable effort may be necessary to remove them from the stand not only because they can take over and dominate the site, but also because they can compete with the main crop (overstory) for water, nutrients, oxygen and space (Gingrich *et al.*, 1965; Brinkman *et al.*, 1965).

At the end of the rotation, when the stand is harvested and reproduced, the direction of succession depends primarily on the conditions created by the cutting and other treatments to both

the physical site and the vegetation. In some cases, the species composition of the regeneration can be adequately controlled by merely regulating the severity or size of the cutting.

Various methods may be used to reduce competition from undesirable species or prepare a seedbed to favour the establishment of preferred species in the new rotation. Prescribed burning is commonly used as a means of reducing hardwood competition in newly established pine stands or to remove heavy litter layers thereby exposing a mineral soil seedbed. Herbicides are also used frequently to eliminate undesirable components of a stand both before and after the cut has been made. Scarifying the soil either during or after cutting operations is another method of seedbed preparation designed to expose mineral soil to favour the establishment of preferred species.

COMPETITION IN THE FOREST ECOSYSTEM

Competition, is the more or less uneven struggle for environmental resources among individuals which have requirements for the same resources, usually at the same point in time. For the most part competition acts in an indirect fashion. For example, the light, nutrients, water, carbon dioxide, and oxygen utilized by one plant are unavailable at that point in time to another organism.

When plants or other organisms exist in close proximity to each other, some will normally develop a competitive advantage over others. Because of their relative positions with respect to the supply of an environmental resource or because of differences in vigour, some organisms will obtain resources from the environment which are necessary to survive and grow and hence, compete for other resources. Others, because of a competitive disadvantage eventually lose vigour and drop out of the community or become stagnated with respect to growth.

Competition for the resources of the environment occurs at all levels within the community; i.e., within species, within life forms, among life forms, and among plants as a group and animals as a group. The most severe type of competition usually occurs among individuals of the same species (**intraspecific competition**), primarily because of their similarity in ecological requirements, tolerances and efficiencies which results in fairly uniform competitive ability. Some species such as red or jack pine, exhibit this uniform competitive ability. Individuals of these species compete so uniformly that the entire community, not just individuals, suffers from the intense competition. However, not all species exhibit a uniform competitive ability among individuals. In fact, in most species prolonged competition among individuals works to the distinct advantage of some while the weaker members in the community eventually drop out of the stand.

Competition among species (**interspecific competition**) may at times be as intense as within species competition. However, usually one or perhaps several species possess a competitive advantage over others and these will tend to dominate the community over long periods. The species which assume this dominance vary according to type of site. The ability to compete and to retain dominance on a particular site depend primarily on how closely the resources of the site meet the requirements of the plant and how efficiently the plant utilizes these resources with respect to its competitors.

Foresters are increasingly aware of the importance of the deleterious effects of competition among individuals of different life forms. Competition from dense perennial grasses will dramatically reduce the survival and growth of planted seedlings and seedlings established from seed. This competition among individuals of different life forms can occur at all levels in the community; between grasses and trees, shrubs and trees, grasses and shrubs, lichens and mosses, *etc.*. The effects of this type of competition on trees in the forest community are highly variable and depend on how fully the trees utilize the resources of the site at any point in time. In some cases minor vegetation such as grasses and herbaceous plants compete effectively with the trees and seriously affect their growth rates. For this reason, controlled fire, herbicides, or other mechanical measures are commonly used for brush control in intensively managed stands.

There are examples of competitive relationships with more direct modes of influence. Perhaps the most common of these are what have been called the **allelopathic** effects of one species upon another. These allelopathic effects are caused by the release of chemicals, such as phenolics, terpenes, alkaloids, or flavonoids, which are collectively known as **allelochemicals**². These compounds can affect the establishment and growth of competition, sometimes of the same species. The effect of these allelochemicals are thought by many to be widespread and significant with respect to plant succession and species dominance in many ecosystems.

A number of species have been shown to be capable of producing allelopathic effects via the release of these toxic or inhibitory chemicals. One species which has been studied by foresters in this regard is black walnut, the leaves of which contain hydroxy juglan which is converted to a substance called **juglone**. Juglone is washed from the leaves and into the soil, or exuded from roots where it acts as a toxic substance to many plants.

It should be understood that the mode of influence of competition as a biotic factor can be either direct or indirect, and competition for the resources of the environment can occur among all the organisms of the community. The distinction between the direct and indirect modes of influence is made on the basis of whether or not one organism directly interferes with the physiological processes of another; that is by the release of toxic substances, or indirectly influences the rate or status of the physiological processes of another; that is by the shading of subdominant crowns or the vigorous absorption of water and nutrients to the detriment of the less vigorous individuals.

DEVELOPMENTAL STAGES OF COMPETITION

For convenience, foresters often recognize three stages of plant community development that apply primarily to even-aged stands.

Isolation Stage

When communities of essentially isolated individuals become established there is no competition among individuals. In forest communities, the isolation period of successful, naturally reproduced stands following some form of clearing in a good seed year is usually very

² Whittaker, R.H. 1968. Chemical ecology among higher plants. *In*: Perspectives in Chemical Ecology. Syracuse: SUNY Coll. of For.

short. There is usually a brief period following seed germination during which individual seedlings are isolated, but it is doubtful that isolation lasts through the first growing season under these conditions.

Communities established by the planting of perhaps 2-year old growing stock of one species at a 2 m by 2 m (6 ft by 6 ft) spacing would be free of intraspecific competition for several years. However, experience shows that competition between the tree seedlings by some of the grasses, herbs, and shrubs can be severe at this stage of development (Richards, 1968; Mann, 1968).

During the period of actual isolation the survival of the isolated plant depends almost entirely on how well the plant is adapted to the physical environment where it exists. For example, widespread failure of seedlings on exposed sites is frequently caused by lethal temperatures at the soil surface. In other situations, failures are due to excessive drying of the surface layers of the soil. In these cases the requirements for water are not met and the seedlings eventually die. Black spruce regeneration failures on humus-covered soils in the north are frequently explained by the lack of available water at the soil surface where the seedling roots are massed.

Consolidation Stage

Consolidation marks the beginning of active competition among individuals of the community and is usually recognized by the touching or mutual shading of aerial plant parts. Prior to consolidation, there is no discernable interaction among plants, and therefore, other plants do not affect growth and development of any isolated individual. At consolidation, the biotic factor of competition for the resources of the site actively affects the well being of all individuals in the community. At the same time, however, the extremes of some of the elements of the physical environment, such as surface soil temperatures, may begin to be moderated at this stage.

Active Competition Stage

Following consolidation, the biotic factor of competition exerts a major influence on the growth and development of individuals in the community. As was previously stated, the effects of competing plants upon each other are mostly indirect; the reason for this being that competition is expressed most frequently through the decreased availability of resources to individuals. One plant affects another by using resources which become unavailable to competing plants.

Not all plants which share the same habitat compete with each other. Different plants may utilize the environmental resources at different times of the year. For example, many of the spring geophytes, such as the ladyslipper or species of *Hepatica*, go through their most active development early in the spring before trees are fully active physiologically.

The degree of influence of the biotic factor of competition can perhaps be better appreciated when it is realized that at consolidation, naturally reproduced stands of eastern white pine commonly are stocked with 100,000 seedlings per acre. If left undisturbed for 100 years, these stands will contain approximately 100 individuals per acre. This means that 99.9% of the stems are normally eliminated from such stands over a 100-year period, the majority of which would be lost due to competition.

During the isolation stage of stand development, the success or failure of the individual is largely a function of how well it is adapted to conditions of the physical environment. During the active competition stage, the success or failure of the individual is dependent upon its ability to transform the available environmental resources into organic matter (i.e., the vigour of the tree) at a greater rate than its closest neighbours. In other words, the success of the individual during the active competition stage is a function of this ecological efficiency in addition to its requirements and tolerances. In temperate forest communities, vigour and efficiency refer to the tree's height growth rate, because the height of one individual relative to the heights of its neighbours ultimately determines its eventual survival.

TYPES OF COMPETITION IN THE FOREST COMMUNITY

Foresters are generally concerned with two types of plant competition in the forest community. One of these is root competition which is competition in the soil for water, nutrients, oxygen, and space. The other major type is crown competition which is competition above ground for light, heat and carbon dioxide.

Root Competition

Foresters know the importance of root competition on the growth and development of forest stands. Forest trees often compete rather keenly for available nutrients and this competition is especially keen on sites that are initially nutrient poor. Competition for soil moisture is more prevalent than competition for nutrients although they often occur together. Since most feeder roots are massed at the soil surface, it is not surprising that competition for the soil-related environmental resources is most severe in the soil layers near the surface. Since this is the zone of competition, it also follows that shrubs and seedlings are fully capable of competing with mature trees for these resources.

Crown Competition

Crown competition is something that can be seen and assessed for individual trees or stands. For this reason, it is often used to guide the timing of various cultural treatments in forest stands. The forester will mark trees for removal which are interfering or will shortly interfere with the growth of a selected "crop" tree. Interference is usually defined as crown interference, which is the shading on the sides of the crop tree crown by the crowns of some less desirable individuals. The relative desirabilities of individuals in the stand may be judged on the basis of species, size, growth rate, age, spacing, location within the stand, probable susceptibility to insect or disease attack, and a host of other possible criteria.

The evidence of crown competition is fairly easily recognized. Intermixed or touching branches, crown erosion caused by the rubbing of branches as the tree sways in the wind, shading of crowns or portions of crowns by adjacent individuals, and the degree of natural pruning all indicate crown competition.

Although crown competition can be assessed at a glance by the experienced forester, it only partially indicates the competitive pressures on a given individual. Therefore, crown competition cannot normally be used as the sole basis for making decisions in thinning or other cultural

operations.

The desirability of crown competition depends upon the goals of the landowner. For timber production, some crown competition at certain times is highly desirable. The goal of forest management in many cases is the production of as much knot-free (i.e., clear) lumber as is economically feasible primarily because clear lumber is commonly worth more. Therefore, when clear lumber is the goal of management, young stands are often grown at fairly tight spacings to encourage natural pruning and at the same time, suppress diameter growth to keep the knotty core of the stem to a minimum. Then, when one or two clear logs have been formed the stand is gradually opened up to permit crown expansion. Following a period of vigorous crown expansion there is usually a period of increased diameter growth which, because the stems are pruned, results in the production of clear wood. Considerable skill and knowledge are required to maintain the increased growth rates while keeping the site fully occupied with desirable crop trees. This would probably be done under the most favourable circumstances by a series of frequent, light thinnings. However, because this pattern of operation may be costly rather than profitable, in the most productive stands these thinnings are often less frequent and heavier. Consequently, the site is normally not fully occupied all of the time by the so-called crop trees.

As another example, if the goal of the owner is maple sugar production, crown competition is generally considered undesirable. Open-grown trees generally yield much more sap than stand-grown individuals at the same age. Hedgerow trees, pasture trees and roadside trees are frequently tapped because experience has shown that trees with large expansive crowns are the best sap producers. Therefore, the silvicultural treatments prescribed for sap production in a developing sugarbush are considerably different from those prescribed for production of clear lumber.

Similarly, when a stand is managed with wildlife as the primary consideration, cover and mast (nut) production may be more important than the production of clear lumber. Consequently the stand would probably be managed to minimize crown competition in both food production and cover areas.

STAND STRUCTURE AND DEVELOPMENT

Forests are managed basically by the arrangement of vacancies within them. These vacancies are created primarily by cutting in the managed forest, but may also result from catastrophic occurrences, such as windthrow, fire, landslides, or climatic extremes. The frequency with which these vacancies occur within a stand, the percentage of the area left vacant, and the severity of the disturbance determine the species composition and the age structure or age arrangement of the resulting stand. If all, or nearly all, of the area is left essentially vacant by a cutting or catastrophe, the resulting stand is usually **even-aged**; it is composed of trees which are of essentially the same age. If, on the other hand, vacancies are created within the stand at fairly regular, closely spaced intervals and only a small portion of the total area is affected each time, trees of many ages occur within the stand, and the stand would be described as **uneven-aged**. These stands are usually characterized by their diameter class distribution (Figures 5.2 and 5.3).

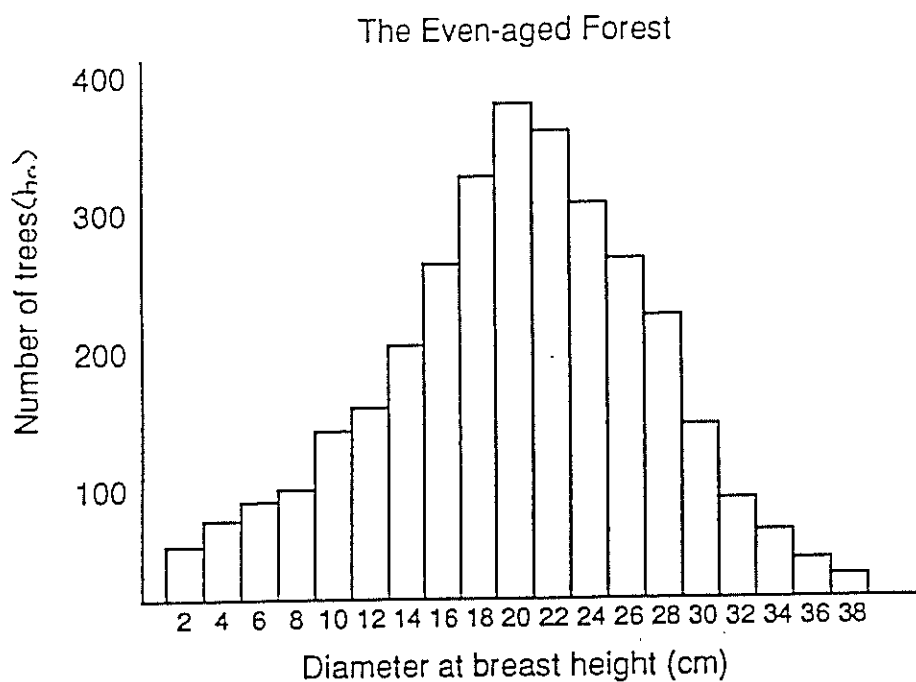


Figure 5.2 Diameter class distribution for a typical even-aged stand by 2 cm diameter classes.

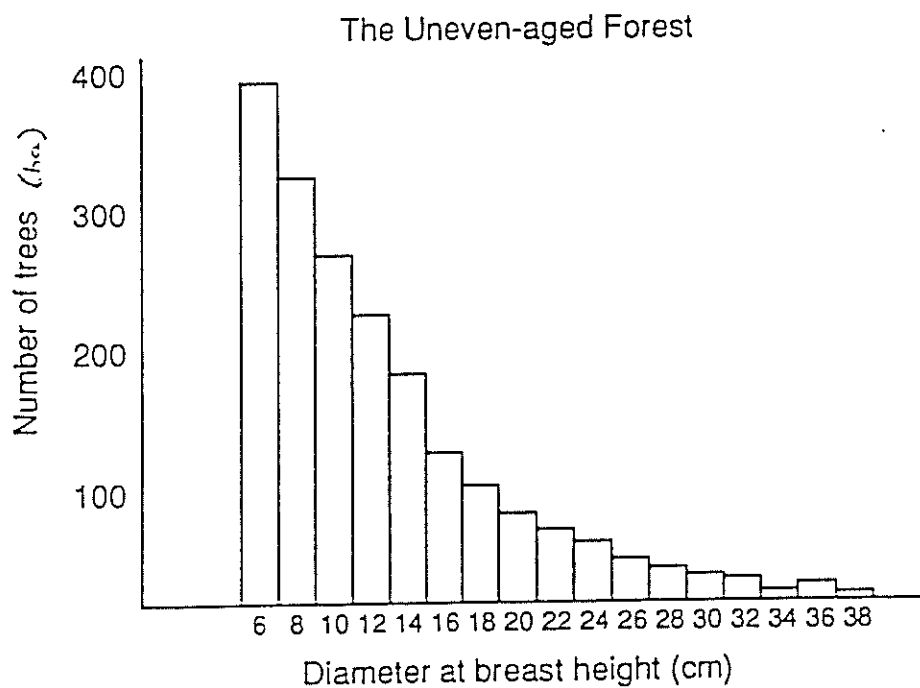


Figure 5.3 Diameter class distribution for a typical uneven-aged stand by 2 cm diameter classes.

DEVELOPMENT OF EVEN-AGED STANDS

Even-aged stands usually result from some type of drastic disturbance whereby an existing stand is destroyed. As a consequence of such disturbances, ecological voids are created in the sense that the site is unoccupied or only partially occupied by living plants. These voids are normally filled rapidly by a variety of plant species. In a managed forest, steps are usually taken to insure that this plant growth consists primarily of desirable species rather than grasses, herbs, shrubs, or undesirable tree species.

Perhaps the simplest example of stand development is that of a pure (one species), even-aged stand. The initial stage in the development of such a stand would be seedling establishment either by planting or natural means. At this stage of development, the survival of a seedling depends on the interaction between the seedling and the physical environment. Growth requirements must be met and environmental tolerances cannot be exceeded for the seedling to survive. Parasites and herbivores such as deer and rodents can affect seedling survival and hence affect establishment of some stands.

As the seedlings grow, they pass through the isolation and consolidation stages into a state of active competition. At this point, competition, in addition to the plant-environment, plant-parasite, and plant-animal interactions, affects the growth and survival of each tree. In this relationship, competition for light appears to be most critical. As the crowns meet and intertwine to form a closed canopy, the lower branches on the stems are shaded and eventually die from the lack of light. Therefore those individuals which are taller than their neighbours have more photosynthetic surface area, and because of this advantage, are able to compete more vigorously for other environmental resources like water and nutrients. This implies that for individuals to survive, they must be at least as efficient in height growth as their neighbours.

Foresters have developed **crown classes** based on differences in the relative positions of the crowns of adjacent trees. The different crown classes reflect the differences in amount of direct sunlight received by the crowns, which for a particular tree depends on how tall it is compared to its neighbours. The standard crown classes are described below in Figure 5.4 (Smith, 1985):

- | | |
|--------------------------|---|
| Dominant (D): | Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the sides; larger than the average trees in the stand, and with crowns well developed but possibly somewhat crowded on the sides. |
| Codominant (C): | Trees with crowns forming the general level of the crown cover and receiving full light from above but with comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides. |
| Intermediate (I): | Trees shorter than those in the two preceding classes, but with crowns extending into the crown cover formed by dominants and codominants. Crowns receive a little direct light from above but none on the sides; usually small crowns are considerably crowded on the sides. |

Suppressed (S): Trees with crowns entirely below the general level of the crown cover, receiving no direct light neither from above nor on the sides.
(Overtopped)

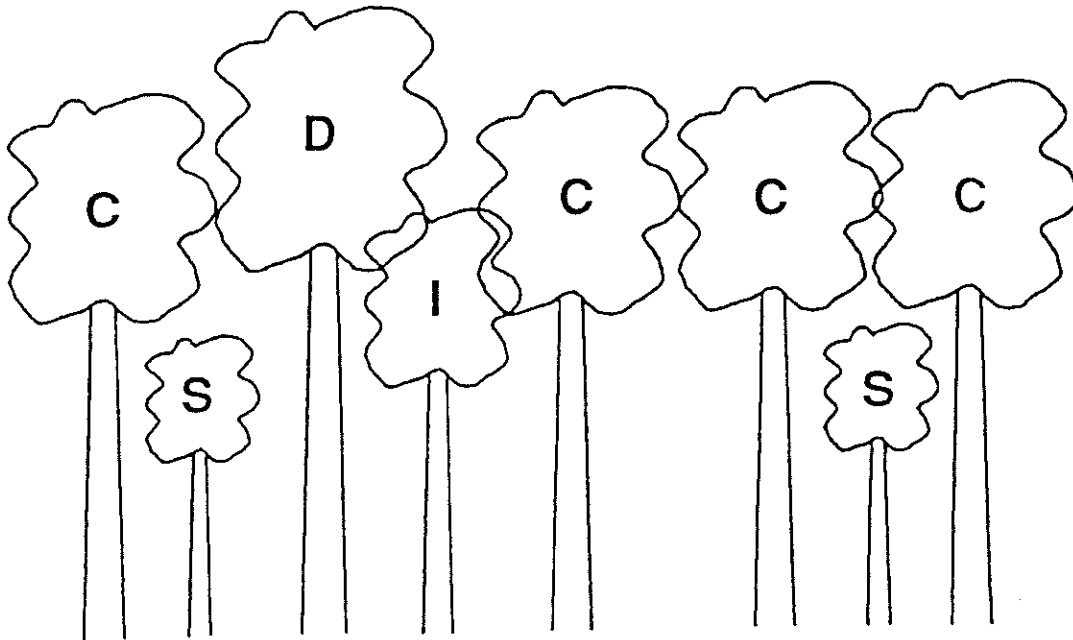


Figure 5.4. Standard crown classes in an even aged stand, cross-sectional view.

In a stand as simple in structure as a pure, even-aged stand, all trees are dominants by definition as soon as the seedlings become established. They maintain this crown position until the crown canopy is formed at the consolidation stage. At this time, the shorter trees have a greater proportion of their live crowns shaded than do their taller neighbours. This slows their vigour and growth so they fall behind in height growth. In the absence of outside interference or the accidental death of one or more of the taller competitors, the shorter trees will move down through the crown classes. They will be outgrown until they are overtopped by faster growing competitors (Guillebaud and Hummel, 1949). Eventually these trees will die from shading unless they can adapt to the reduced light under the dominant-codominant canopy. Shade-tolerant species possess the ability to adapt to the lower quality of light in the understory environment. Therefore, to distinguish between overtopped trees which are capable of surviving under a closed canopy and those which are not, the lowest crown class is frequently subdivided into the "suppressed" and the "oppressed" crown classes (Ward, 1964), the latter being defined as dead or dying individuals (Figure 5.5).

The diameter growth of an individual in an even-aged stand is closely related to its crown class with the dominant and overtopped individuals respectively having the largest and smallest diameter growth rates. The death of trees as the result of competition continues as long as the crowns maintain a closed canopy. The continuum of crown classes in a stand at any point in time is reflected in the distribution of the tree diameters. For even-aged stands, the diameter distribution approximates that of the normal distribution (Fig. 5.2).

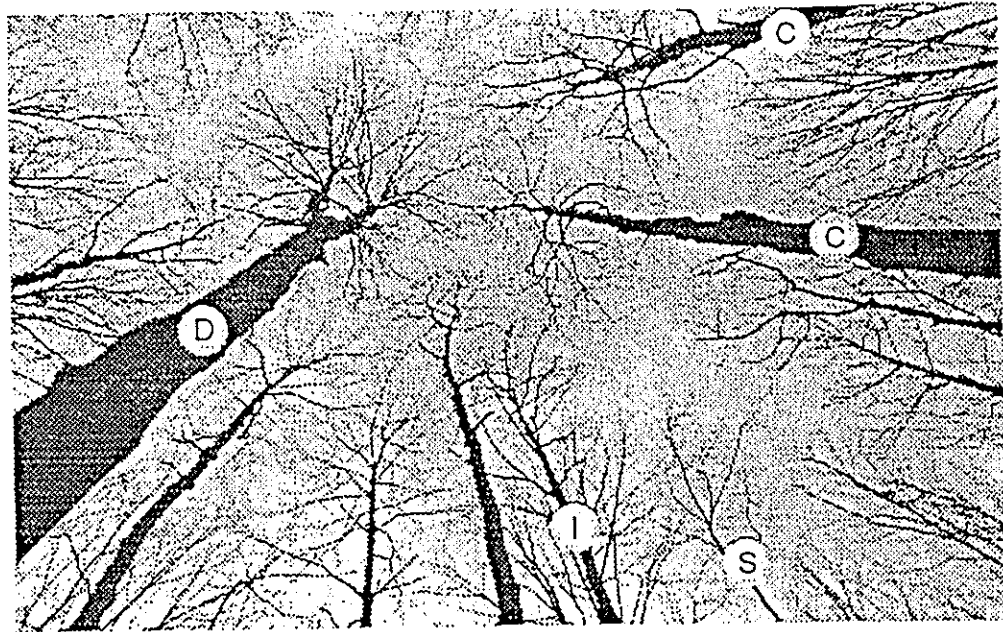


Figure 5.5. Photograph of the canopy from the forest floor showing the different crown classes. Dominant trees (D) extend above the main canopy level- Codominants (C) form the main canopy and Intermediates (I) and Suppressed (S) trees are below the main canopy.

The development of mixed, even-aged stands generally follows that described for pure, single-aged stands with several important exceptions. The first of these is that there are differences in height growth for different species. As a consequence, the crown classes may be identifiable with species: the stand becomes stratified vertically on the basis of species.

Age differences of the seedlings may also affect both the composition of the resulting stand and the composition of the various strata within a stand. For example, if one species produces abundant seed ten years after another species, the seedling of the second species may be at a disadvantage because of its late entry into the race for light and growing space.

In mixed stands, the biotic factors of parasitism, disease and herbivory may be biased toward particular species in the mixture. For example, deer prefer certain species such as red oak and can thereby exert a major influence on the composition of the developing stand. Similarly, some of the more destructive diseases are specific to a tree species. Because of this, mixed stands are often considered to be desirable since the diversity of species assures some protection against losing the entire stand to a pest or disease that may affect a single tree species.

As a general rule, thinnings in even-aged stands are made to favour the leading trees, that is those in the dominant and co-dominant crown classes. This is done primarily because (1) many tree species in intermediate or lower crown classes cannot recover their vigour after thinning and (2) the time necessary for other trees to recover their vigour after release is often prohibitive.

This does not mean that trees of the dominant crown classes are the most desirable in all cases. Desirability as indicated by value is relative and depends primarily on ownership

objectives and local markets. For quality sawlog production, the dominants can be too coarse in terms of large diameter limbs and/or poor stem form, whereas for mast or seed production, maple sap production, or aesthetic value these coarse individuals may be preferred.

The silviculturalist can influence the character of stands at different stages of development to maximize their net worth to the landowner. Within environmental constraints, the stand and the physical site can be manipulated to favour preferred species and to maintain growth rates within these stands. By manipulating the stand to produce trees with certain crown and/or stem characteristics, production can be oriented toward a specific market or product. However, to make effective decisions, the silviculturalist must know the constraints, which include those of the physical site, existing stand, and socio-economic climate.

DEVELOPMENT OF UNEVEN-AGED STANDS

In uneven-aged stands the conceptual model of a stand developing as a unit over a period of, perhaps, 70 or 100 years does not apply. In the truly all-aged forest it would be possible to observe all stages of even-aged stand development at one time at various points in the stand. In the unmanaged forest, the all-aged structure results from the loss of individuals from the stand every year and their replacement by seedlings. In the managed forest, the same effect would be created by light annual cuttings primarily from the overstory. Therefore, at any one point in time, it would be possible to observe clusters of perhaps 100 seedlings occupying the space previously held by one large individual which either died or was killed recently. It would also be possible to identify individuals which were just breaking into the dominant canopy, the sole survivors of a process which began with the loss of one large tree from the stand. In this vacancy a large number of seedlings would be established and the subsequent competition among them, and between them and the existing individuals in the stand would lead to their race for the opening in the canopy.

It should be fairly obvious that the list of species which form uneven-aged stands is much more restricted than the list of species which are successful in even-aged stands. In fact, most of the species which are found in uneven-aged natural stands can be grown in managed even-aged stands. However, most of the species found in natural stands with even-aged structure cannot be grown in uneven-aged stands.

The characteristic that is most important in determining the ability of a species to survive in, and be a consistent component of uneven-aged stands is **shade tolerance**, or the ability to exist and grow in the shade of other, larger individuals. In addition to the ability to tolerate shade, individuals of these species must also possess the ability to compete with the more dominant individuals for water and nutrients. Trenching experiments have been done whereby trenches are dug around stands to prevent invasion of roots and eliminate competition. The results of these experiments have indicated that the scarcity of ground vegetation on the forest floor is sometimes due primarily to the lack of light at the ground level, but in other cases, it has been shown to be due principally to competition for water and nutrients.

The conventional classification of individual trees into crown classes in even-aged stands cannot be applied directly to trees in uneven-aged stands. In the even-aged stand, vigour of

individuals is related to crown class and their movement through the crown classes is essentially downward. In the uneven-aged stand, the trees begin their struggle for survival in the understory and, if they are successful, move up through the understory into the main overstory canopy. Also, because of their silvical characteristics, the vigour of species prominent in uneven-aged stands is not necessarily related to their crown position.

Because of these relationships, the diameter distribution in uneven-aged stands does not resemble the normal curve. Instead, it is characterized by an inverse J-shaped curve with the largest number of trees found in the smallest diameter class and the smallest number of trees found in the largest diameter class (Fig. 5.3).

DEVELOPMENT OF STRATIFIED STANDS

In many forest stands which have not been under intensive management or have been mismanaged, and in some intensively managed stands as well, the stands assume a stratified appearance. Each layer may differ with respect to species and age and sometimes with respect to between-layer age class distribution. For example, the dominant canopy may consist of two or more species and may be essentially even-aged, while a subdominant layer may consist of a single species, such as hemlock, which is decidedly uneven-aged. In other cases, both layers may be of the same age. This type of complex structure is common in many areas of North America. The cultural treatment and management of such stands is considerably more complex than that of either strictly even-aged stand or uneven-aged stands.

The central question to the silviculturalist working with layered or stratified stands is to decide if it is desirable to permit the character of the stand to change by managing each successive layer in turn. An example of this type of management in a white pine-hardwood-hemlock forest is given by Smith (1985). A full rotation for this type of stand might consist of three successive rotations: one for the dominant white pines, followed several decades later by one for the hardwood layer which would assume dominance following removal of the white pines, and one for the hemlock layer several decades after the hardwood harvest.

Some foresters, on the other hand, would undoubtedly look upon this management of succeeding layers as not only undesirable in light of the goals of management, but as unprofitable as well. The choice between methods depends primarily upon the diversity of markets in an area for the species in the various layers, the value differences of the species in the various layers, and on the ability of the subdominant species to respond to release. It is also possible that by growing the species of one or more of the subdominant layers for long periods of time, site changes may be effected which would be costly to overcome for a different species at a later date. For example, the effects of the acid litter deposited during a 40-year period of residence of a pure hemlock stand may be difficult to overcome if, following removal of the hemlock, efforts are made in response to market conditions or managerial priorities to establish a species which is intolerant either to an accumulation of litter or the acidity of the surface soil or both. There is also the risk that if the management of individual layers is carried out over large areas the natural seed sources for species in the more dominant layers will be effectively removed.

REVIEW

1. The **forest ecosystem** is comprised of all the living and non-living components of a given area that interact amongst one another.
2. The **forest stand** is distinct from the forest ecosystem in that the stand simply refers to the trees and not their environment.
3. **Plant succession** is the directional change in vegetation in a community through time. Ecological disturbances create gaps in an ecosystem where new life is initiated. Early vegetative communities are gradually replaced by more mature plant communities until an equilibrium is reached with the **climax community**.
4. **Primary succession** occurs on land areas that did not previously support vegetation. **Secondary succession** occurs in areas where vegetation has grown previously but some sort of disturbance has created a gap in the ecosystem.
5. The successional sequence may be broken down into four discrete stages: the **pioneer** or initial establishment stage, the **consolidation** or early successional stage, **subclimax** stages where the vegetation community has developed substantially but has not yet reached equilibrium, and the **climax** stage where the vegetative community is relatively stable.
6. With a good knowledge of forest succession, the forester or landowner can apply its principles to manage the forest for specific tree species which are unique to certain successional stages.
7. **Even-aged** stands are usually initiated when a drastic disturbance creates an opening in a forest stand, and the trees that colonize generally form a stand in which the trees are approximately the same age.
8. In an **uneven-aged** stand it is possible to observe trees of all different ages. As larger old trees die and fall down, seedlings quickly fill in the new gaps. The ability of trees to survive in an uneven-aged system depends primarily upon their ability to tolerate shade (**shade tolerance**).
9. **Stratified** stands, those with distinct age layers, develop in stands that have been mismanaged, managed too intensively, or have been subjected to irregular types of disturbance.
10. **Competition** is the uneven struggle for resources among individuals that have the same requirements. **Intraspecific competition** is that between members of the same species. **Interspecific competition** is that between members of different species.
11. There are three developmental stages of competition: **isolation**, the initial stage where there is no competition among individuals; **consolidation**, which marks the beginning of active competition; and **active competition**, which exerts a major influence on the growth and development of individuals in the community.

12. Foresters are generally concerned with two types of competition: **root competition** for available moisture and nutrients, and **crown competition** for light.

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Chapter 6

PLANTATION ESTABLISHMENT AND MANAGEMENT

SELECTION OF PLANTING SITE

The most important factor in the establishment of a successful plantation is matching tree species requirements with site conditions. Most tree species are selective and will grow well only on sites that satisfy their individual needs. If planted on sites where climate, soil or drainage conditions are incompatible with the species requirements, seedlings will grow poorly or die. The closer the match between requirements of a species and actual conditions of a planting site, the greater the probability for a successful plantation¹.

MATCHING TREES WITH SOILS

Often species currently growing on a site will offer the best indication of growing conditions -- like meeting the neighbours to get a feel for the neighbourhood. A particular species can be expected to grow well on a site, if it prefers similar growing conditions to those species already present. Other vegetation will give an indication of soil fertility. A dense cover of vigorously growing vegetation generally suggests good fertility, whereas sparse, slow-growing vegetation is indicative of low fertility or inadequate moisture. Knowledge of soil type, drainage conditions, species present and their vigour, should give a good idea of what will grow well on which site.

A more technical approach to defining site suitability involves determining soil texture, depth of topsoil, pH, drainage, climate and general fertility of the planting site. Fertility may be assessed by laboratory analysis of soil samples. Soil Survey Reports and maps, published by the Research Branch of the Canada Department of Agriculture and the Guelph Agriculture Centre, provide useful information on soil types in a prospective area. This general information must then be supplemented by detailed information about the conditions of the actual planting site.

¹ Preferred site conditions of many Ontario species are discussed in the following books: *Hardwood Planting on Abandoned Farmland in Southern Ontario* by F.W. von Althen, Forestry Canada, 1990 and *Native Trees of Canada* by R.C. Hosie, 1975.

POTENTIAL FARM PLANTING SITES

Hardwood trees grow best in deep, fertile, moist, but well drained soils. However, these are also the best agricultural soils and are seldom available in large tracts for **afforestation** (the conversion of unforested land to forest). Suitable areas that are available include small sites where farm machinery cannot be operated efficiently, sites that are inaccessible for part of the year and sites that are not suitable for farming. In southern Ontario, good hardwood planting sites are found along streams, on lower slopes and in depressions where topsoil has accumulated. Abandoned orchards, gardens, and agricultural fields where the topsoil is at least 40 cm (16") deep, are also good. Most areas taken out of agricultural production because of infertility or poor drainage, contain small areas that are capable of growing high-quality hardwood timber. Although these pockets may cover less than a hectare, a small area of veneer or sawlog quality black walnut (*Juglans nigra* L.), red oak (*Quercus rubra* L.), or other valuable hardwood, may yield a higher return than pulpwood grown in a much larger area. The remainder of these tracts may be better suited to conifer plantations; pines on the sandy, well drained sites and spruce or fir on the fine textured, moist sites. Hardwood seedlings will not produce high-quality timber or beautiful shade trees when planted on dry, exposed slopes and ridges, or in areas with shallow topsoil and heavy, compacted clay subsoil. Assistance in evaluating site conditions and deciding which species to plant may be obtained from the Ontario Ministry of Natural Resources (OMNR) or the local Conservation Authority.

PLANNING AND LAYOUT

Before proceeding with any discussions of plantation establishment aspiring growers should be cautioned about the number of trees to plant initially. Regardless of future production goals, starting with modest numbers is wise. Frustrating failures, resulting from a lack of experience, are not uncommon to any new venture. These temporary setbacks can be accepted and overcome more readily if they involve small numbers of trees. Managing a modest number of trees, from planting through harvest and sales, will provide invaluable experience, and indeed may ensure the future success of the enterprise, especially in reference to Christmas trees (McPhee, 1982).

Planning and layout of the site goes hand in hand with site preparation and is equally important. Determining tree row direction will depend on topography and the purpose of the plantation. For example, tree rows should be planted along the contours of hills to reduce erosion. Rows in a maple orchard should be laid out with sap collection in mind. Planning where access roads will go is particularly important when establishing Christmas tree lots and maple syrup plantations. Roadways play a role in tree access for maintaining and harvesting trees as well as public access in a cut-your-own Christmas tree system. The location of roadways and the sugar house are important in a maple orchard, since they affect how main lines are laid out, how sap is collected and how public tours are conducted. Time spent on planning and layout can save much aggravation later.

SPECIAL CONCERNS

Trees may not be a welcome addition in all locations. Keeping the following things in mind while planning the plantation will help avoid future problems:

1. Only low growing species should be planted near overhead wires, with a minimum horizontal distance of 10 m (30 ft) between trees and overhead wires; further for large crown species.
2. A distance of 5 m (15 ft) should be allowed between trees and heavy traffic areas. One should also be aware of the potential for obstructing motorist's view at corners. Low growing shrubs, or removal of lower tree branches may be options in such locations.
3. The chance of creating snow drift problems can be reduced by thinking about wind flow patterns around the trees and altering their position and culture accordingly. (See Chapter 7 - Windbreaks).
4. At least 10 m (30 ft) clearance should be left along one side of drainage ditches to allow for maintenance.
5. Caution should be taken when planting trees near tile drains since tree roots may plug them. Soft maple, willow and other lowland trees are particularly notorious for this. A minimum distance of 10 m (30 ft) should be kept from tile drainage systems; more if the tree has a wide-spreading lateral root system.
6. Tree roots may damage building foundations, when planted too close. Five metres (15 ft) is usually a safe distance for most trees unless they have large lateral rooting systems.

SPACING

There is no ideal spacing for planting all species on all sites. Spacing is therefore determined by a compromise among growth and access requirements, purpose of the planting, wishes of the plantation owner, the economics of plantation establishment and tending.

To plant trees at closer spacings than is ultimately desired when full grown, requires more seedlings, but offers an opportunity to thin out poor quality trees, and allows for some mortality. When thinned regularly, such plantations produce trees of excellent form and acceptable diameter growth. Recently, plantations have been established at wider spacings and acceptable form has been obtained by pruning. Spacing has little effect on height growth.

The advantages of wide spacing are:

1. Rapid diameter growth.
2. Lower planting costs per unit area.
3. Fewer or delayed thinnings. (less chance of expensive pre-commercial-thinning).
4. Facilitates use of large equipment.

The disadvantages are:

1. Inefficient utilization of the growing space for a large part of the rotation.
2. Delay in canopy closure which, in turn, delays natural weed and grass control by shading.
3. Poor stem form and heavy branching resulting in higher pruning costs.
4. Possible requirement of more refilling due to mortality.

For most plantations, it is recommended that more trees be planted than are desired at rotation age. One may either plant more trees of the same species or interplant with another species that can be removed when the crop trees require additional growing space.

Although spacing varies with species and site, a spacing of 3 m (10 ft) between rows and 1.5 m (5 ft) within rows is commonly used for hardwood plantations. Theoretically, this spacing requires the planting of 2,222 trees/ha (871 trees/ac). However, 85% (1,890 trees/ha or 740 trees/acre) of this number is usually a good estimate of the actual number of trees needed after allowance is made for edges and small unplantable areas such as access lanes. Therefore, the approximate number of trees required to plant an area may be calculated as follows:

$$(\text{field width/between row spacing} \times \text{field length/within row spacing}) \times 0.85$$

This spacing (3 m by 1.5 m) allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control. It promotes reasonably early canopy closure to shade out the competing vegetation, allows for mortality and removal of trees of poor form, and requires at least one pre-commercial thinning. An accepted practice for many years in conifer plantation establishment has been 1.8 m by 1.8 m (6 ft by 6 ft) spacing. Experience has shown that altering this accepted standard to between 2.5 m and 3 m (8 and 10 ft) spacing between rows may be necessary for access, especially in Christmas tree plantations. Also, the 1.8 m by 1.8 m spacing usually requires pre-commercial thinnings, and with poor markets for small materials, wider spacings may be necessary to ensure that young plantations do not stagnate due to overcrowding. Table 6.1 offers some spacing alternatives for different species.

Table 6.1 Guidelines for tree planting (Midhurst Nursery, 1989).

SPECIES	SOME RECOMMENDED SPACING	WHERE TO PLANT (soil type)	RESTRICTIONS
White Pine	6 ft x 7 ft (1.8 m x 2.0 m)	moist, well-drained sandy loams, sands, clays	avoid dry sands or exposed sites
Red Pine		deep, well-drained sands, sandy loams	avoid alkaline soils, frost pockets and heavy, poorly drained soils
Jack Pine		well-drained soils, dry sites	avoid planting in southern Ont. where red or white pine will thrive
Scots Pine	6 ft x 6 ft (1.8 m x 1.8 m)	well-drained soils; will survive on poor sands, shallow soils and high lime content soils	avoid shady sites and poorly drained soils
White Spruce	6 ft x 7 ft (1.8 m x 2.0 m)	moist sands, sandy loams, clay loams and well-drained clays	avoid frost pockets and very wet or very dry sites
Black Spruce	- 6 ft (1.8m) spacing for Norway or white spruce in a windbreak	wide range of sites including very moist and very wet sites	avoid very dry, exposed sites
Norway Spruce		well to imperfectly drained sandy loams, loams and clay loams	avoid dry sites; wet, poorly drained sites; frost pockets
White Cedar	6ft x 6ft or 4ft (1.2m) apart in windbreaks	wide range of sites; will grow on acid or alkaline soils, shallow soils	avoid excessively dry sites
Tamarack	6 ft x 7 ft	wide range of moist sites including swamps, heavy clays, coarse sands	avoid shady areas
European Larch		well-drained loams and sandy loams	avoid shady areas, frost pockets, poorly drained sites and planting large pure stands
Red Oak	5 ft x 8-10 ft (1.5 m x 2.5-3 m) - plant in small blocks of 5-10 rows	deep well-drained sandy loams and loams; plant blocks in white pine or re pine plantation	avoid heavy clays, shallow soils, shady areas, wet or exposed sites
White Ash		deep, fertile, well-drained soils - eg. sandy loams, clay loams; plant blocks in white pine or white spruce plantation	avoid dry, infertile or poorly drained sites
Green Ash		wide range of sites, does better than white ash on imperfectly drained or moist sites	avoid infertile sites
Silver Maple		deep moist soils - eg. moist loams, silts and clays found along rivers and swamps	avoid exposed sites and dense shade
Black Walnut	7 ft x 7 ft (2 m x 2 m) in mixture with white pine	deep, moist, well-drained, fertile sandy loams, loams, silt loams	avoid infertile or dry sites; plant only in Southwestern Ontario
Carolina Poplar	6 ft (1.8 m) apart in a windbreak	wide range of sites	avoid shade, shallow soils, compacted soils and poorly drained soils
Black Locust	6 ft x 6 ft		avoid very wet or shady areas

SITE PREPARATION

The need for site preparation cannot be over emphasized. Site preparation facilitates ease of planting, seedling growth rate and survival, quality, future weed control effectiveness and management costs all depend on site preparation. Although necessity for site preparation varies with site, in general, the most intensively prepared sites show the best results with the least additional effort.

WEED CONTROL

Site preparation may include ploughing and discing, mounding, roto-tilling, chemical control of the competing vegetation, mowing, or a combination of these techniques. Weed control may also be dealt with at the time of planting by mulching. The methods used will depend on soil condition, topography, drainage, accessibility, cost considerations, landowner preference, and density and composition of existing cover. Fields with light grass or weed cover may not require preparation for planting. Unfortunately, most sites require some form of treatment. Grass sod and perennial weeds are a young tree's strongest competitors and must be controlled for successful seedling survival and growth. Under no circumstances should the success of a plantation be jeopardized by skimping on initial site preparation and weed control.

A good method of site preparation, for spring planting in a field with dense grass and weeds, consists of killing the established vegetation early in the previous fall by spraying with glyphosate (trade names Roundup® and Vision®, Appendix A)², followed by ploughing and discing 1 or 2 weeks later. This combination of treatments destroys all weeds, including deep-rooted perennials, and improves soil aeration and water movement. It also stimulates microbial activity and incorporates organic material in the soil, thereby improving organic-matter content (von Althen, 1990). In addition to boom sprayers on tractors for large areas, several types of manual sprayers are available for small, widely spaced areas or for selective spraying (Fig. 6.1). The person spraying should be certified and follow manufacturer's instructions on the label.

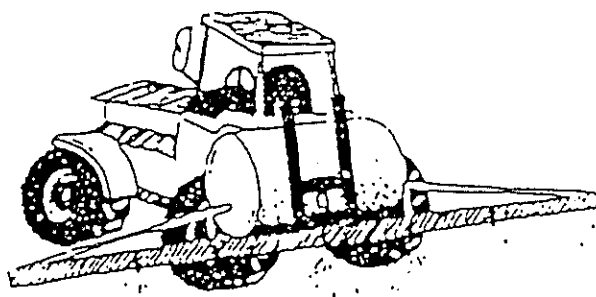
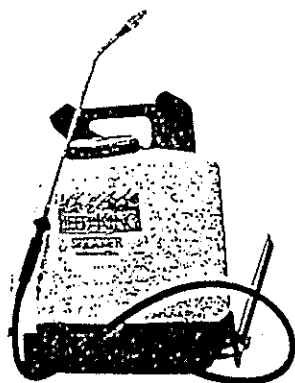


Figure 6.1 a) Backpack sprayer, b) Boom Sprayer

² The identification of commercial products is solely for the information and convenience of the reader, and does not constitute an endorsement by the author.

Herbicides are used in combination with cultivation because elimination of grasses by mechanical means is very difficult, requiring several years of intensive cultivation. Simazine works well for controlling grass, but is not as effective against deeper rooted annuals and perennials. Glyphosate is very effective at controlling grasses, but is expensive and must be reapplied. Many herbicides, including simazine, control most broadleaf weeds effectively, but are relatively ineffective against grasses at application rates low enough to be tolerated by hardwood species. There are a variety of herbicides registered for use on the farm, but not all agricultural herbicides are permitted for forestry purposes. The Annual Guide to Weed Control (OMAF, 1992) is a useful source to help the landowner decide which herbicide is best for their particular situation. It provides information about the chemicals, what each is used for, and their recommended application rates.

Cultivation loosens soil to facilitate rapid root elongation, which is vital to early growth and survival of the outplanted seedling. Herbicide without cultivation may kill weed competition, but does not break up the root mat. The presence of dead vegetation can reduce erosion, but creates two other problems. First, it provides shelter for rodents which will girdle young trees, and second it promotes root damaging soil cracks around young trees on clay soils. When the weeds die and dry up, the soil dries out and cracks. The cracks tend to occur around the trees because the weed root mat, which holds the soil together, is weakest where it has been broken to plant the trees.

STRIP SITE PREPARATION

Some areas are not suited to the use of both herbicide and cultivation. For example, controlled vegetative cover is desirable on rolling fields with light soils because cultivation would leave the site open to erosion. In this instance mowing, spraying or a combination of the two may serve to control competition while protecting the soil. When spraying, ploughing and discing of the entire plantation are not feasible or desirable, ideally strips at least 1.8 m (6 ft) wide should be prepared for planting as outlined above. On abrupt or steep slopes that are difficult to mow with tractor-powered equipment, herbicide treatment may be the best option or may be combined with cultivated strips. Tree rows should follow the contour of the hills to minimize erosion. In general, chemical plus mechanical site preparation and treatment of the entire area results in better tree growth than either chemical site preparation alone or site preparation in strips. However, costs and benefits need to be compared for each situation, since this can be an expensive option.

SINGLE TREE SITE PREPARATION

Individual trees may be planted on weed-free spots prepared by an application of glyphosate in autumn before spring planting. The individual carrying out spraying must be familiar with the correct application procedure, including calculation of dosage and method of application. The prepared spot should be at least 1.8 m (6 ft) in diameter. The larger the cleared area the better, because both competition and danger of girdling by rodents is reduced. While single tree site preparation is acceptable, the methods of site preparation previously described result in better seedling growth.

WHEN TO PLANT

It is best to transplant trees while they are dormant, in early spring or fall, to minimize stress. Seedlings, whips and cuttings should be transplanted in spring because they are not as hardy as larger stock and are also more subject to frost heave. Larger stock can be transplanted in spring or fall, although fall planting sometimes carries a higher risk of mortality. Summer planting of large container stock can be done successfully, but is very stressful to the actively growing tree. The combination of summer heat with the tree's demand for water increases the chance of roots drying out during process of transplanting.

PLANTING STOCK

The success of any plantation also depends on the quality and suitability of the planting stock. Good planting stock should have sturdy stems with well developed terminal buds, well branched root systems and balanced root-to-top ratios (root:shoot).

Forest managers have often expressed a preference for large transplant stock in the belief that planting large trees would eliminate the need for site preparation and weed control. This is probably true for individual, large trees. However, when transplants 1.2 m (4 ft) high and up to 5 years old were planted in a weed-infested soil without prior site preparation or subsequent weed control, they did not grow as well as seedlings planted on the same site with site preparation and post-planting weed control (von Althen, 1990). Transplant stock is also very expensive to produce, transport and plant. Growth of all classes of planted stock on unprepared sites is generally inferior to that of seedlings planted in ploughed and disced soils treated with herbicides. Hence, it is much more economical to spend the available money on site preparation and weed control than on the purchase of large transplant stock.

The quality of stock should be assessed when it is received, bearing in mind that most tree planters have no control over the quality of the planting stock that they receive from the nursery. Much of the damage to seedlings, however, occurs after they leave the nursery. To ensure top quality planting stock, tree planters should be sure to 1) pick up the stock as soon as it is ready, and 2) prevent damage during transportation to the planting site. Undersized or damaged seedlings should be discarded, as they seldom produce trees of acceptable size or form. Money spent on planting inferior seedlings is wasted.

Seedlings can be purchased through the Ontario Ministry of Natural Resources, private nurseries, or some Conservation Authorities. Quality of stock can vary from year to year and nursery to nursery, so it is best to investigate stock before purchase. Stock quality at the OMNR nurseries meets very rigid standards. Orders through the OMNR or Conservation Authorities should be placed 8 months to a year in advance to ensure stock availability. Larger stock ranging from 30 cm to 3 m (1 ft to 10 ft) in height is available from private nurseries and some Conservation Authorities at prices based on size, quality, and species. By contacting the nearest District Office of the OMNR, any landowner can secure technical assistance and application forms for nursery stock.

TYPES OF STOCK AVAILABLE (Fig. 6.2)

- Plug seedlings** 1 year-old stock grown in small plastic tubes or similar container.
- Cuttings** Some trees such as poplar (*Populus sp.*) and willow (*Salix sp.*) are commonly grown from cuttings taken from one-year-old stems. The cuttings should have at least three buds and be about 20 cm (8") long and 1 to 2 cm (0.5 to 1") in diameter.
- Bare Root stock** One- to three-year-old seedlings, with little soil on the roots, may be shipped in plastic lined paper bags. This is the most common way to buy seedlings.
- Container stock** Older seedlings up to a couple of meters high are sold in various types of containers, including fibrous and plastic pots. Some container stock is planted in the pot shortly before shipping, while others are either grown in the pot or potted the previous fall.
- Balled stock** Trees two metres or more high, which have been dug up and the root/soil wrapped in burlap, are balled stock. Large balled stock is dug with a tree spade and set in undersized wire baskets for transport.

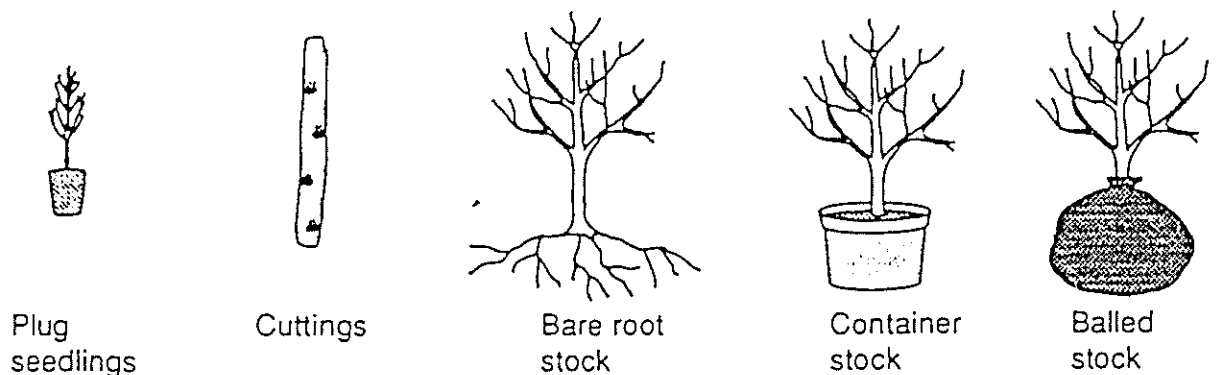


Figure 6.2 Types of nursery stock.

Stock is usually designated by two digits which refer to the number of years it grew in the greenhouse or seedbed and the number of years it has been outplanted. For example, a tree designated 1+2 was grown for one year in the greenhouse or seedbed and was transplanted out for 2 years.

The following are some of the things to look for when choosing quality large stock:

1. Cuts or scrapes on the trunk of the tree are undesirable. While these are not life threatening for the tree, they imply the tree is already under stress and offer a point of entry for disease.
2. Signs of canker, other disease or insect problems should be avoided.
3. Trees with some taper in the trunk are preferred to tall skinny trees that are apt to break in the wind.
4. Healthy, well developed root systems are more important for establishing a tree than its current form, which can be altered with pruning. To obtain acceptable survival and growth rates, research suggests that oak seedlings, for example, should have a minimum of 5 large lateral roots (Thompson and Schultz, 1992).
5. Trees with some scar tissue forming around pruned branches are preferred to trees that are freshly pruned, because the healing process is already well progressed.
6. The occasional broken branch is insignificant, since once pruned off, it will have little affect on the condition of the tree.
7. Balance of tree height and diameter are more important than age.

HANDLING BARE ROOT STOCK

Poor survival in the first year is often the result of substandard handling practices from the time the seedlings leave the nursery until they are planted. Proper handling involves keeping the whole tree cool and moist and the trees unbroken and unscraped. Tree roots are generally packed in moist peat moss or sealed in polyethylene-lined paper bags to protect them in transport. However, care must be taken to protect them from excessive heat from direct sunlight or exposure to drying winds. Roots dry out very quickly, causing mortality. To prevent damage from heat stress, stock should be stored in the shade at the planting site. If shade is unavailable, tarps may be used for short periods of time, if they do not trap heat. Standard tarps are very good at trapping heat and can be worse than no tarp at all, except when used as a roof or tent. Silvicoool tarps do not trap heat, and hence, are far better than standard tarps. They are also well within budget for anyone doing much planting.

Bales or bundles of seedlings should not be piled, except briefly during transportation, to prevent physical damage and heat stress. Damage also occurs when trees are left sitting in water for more than an hour. These types of damage may not be apparent at the time of planting but are revealed in poor first-year survival and growth.

Seedlings should be planted as soon as possible after they arrive from the nursery. Poor weather, machine breakdown, planting site preparation, and shortage of seasonal labour can all

delay a planting operation. If delay is unavoidable, the seedlings should be stored in a cool place and their roots kept moist at all times. They can be stored temporarily in the polyethylene-lined nursery bags, but it is crucial that bag temperature never exceed 10 °C and bags should never be stacked more than two high. Cold-storage facilities at nearby orchards are ideal for storage, but if these are not available, root cellars, basements, or other cool places may be used. Hardwood seedlings should not be stored with apples or any other fruit which produces ethylene, unless ventilation is good. Ideally storage temperature should be approximately 2° C; trees should never be frozen. If planting is delayed more than a week and no cold-storage facilities are available, seedlings should be removed from the shipping containers and heeled-in at a shaded, moist, but well drained location.

Heeling-in is a last resort. It is done by placing individual bundles of trees in a trench deep enough to hold the roots and pressing soil firmly around the roots to exclude air. These heeling beds must be kept moist. The trees can then be transferred to the planting site anytime before the buds start to burst. Moving trees during this time of **flushing** will reduce their chance of survival. Therefore, if you know ahead of time the trees may be in the heeling beds past flushing, you may want to heel them in individually, close together rather than in bundles. This way you can leave them until the following spring to plant them.

PLANTING

BARE ROOT STOCK

Careful planting of stock will be rewarded with a high survival rate. Careless planting is reflected in poor growth, mortality and seedling form development. **Regardless of planting technique, the trees must be straight, undamaged and buried to the root collar. Their roots should be evenly spread, with the soil packed firmly around them to remove air pockets.** Trees planted at an angle may either develop a bend, or a new vertical shoot. A bend in the stem gives the tree poor form from the start. A new vertical shoot means the original stem must be pruned. Extra work is required and valuable height increment is lost. For the promotion of good root development, root systems should be spread to avoid bunching, and packed well with soil to ensure good root contact with the soil. Enlarge the hole rather than curling roots to make them fit a small hole. This will promote good root form since roots grow downwards from the root tip. If the hole cannot be expanded to accommodate roots that are too long, the roots should be pruned off rather than twisted around or doubled up. Figure 6.3 demonstrates root systems that can develop from proper planting and poor planting. When packing the soil it is very easy to skin the bark off the seedling. Care should be taken to avoid this. A solid blow to the soil about 10 cm (4") from the stem with the heel of the foot will serve to remove air pockets, improve root to soil contact, and firm up the tree.

It is very important that trees be planted at the correct depth. Soil should be level with the **root collar**, which is a slight swelling at the soil level before the tree was dug up. A transition in colour between the root and stem may also help identify the root collar on some species. If the region below the root collar is not buried, the tree will tend to be more susceptible to frost

damage and disease. If buried too deep the stem is susceptible to rot. Planting the tree only slightly deeper than the root collar is ideal because it allows for soil settling. This allowance for settling is especially important where machine planting pushes a ridge up above the planting slit. The landowner should keep these factors in mind when selecting a planting method and supervising the planting operation.

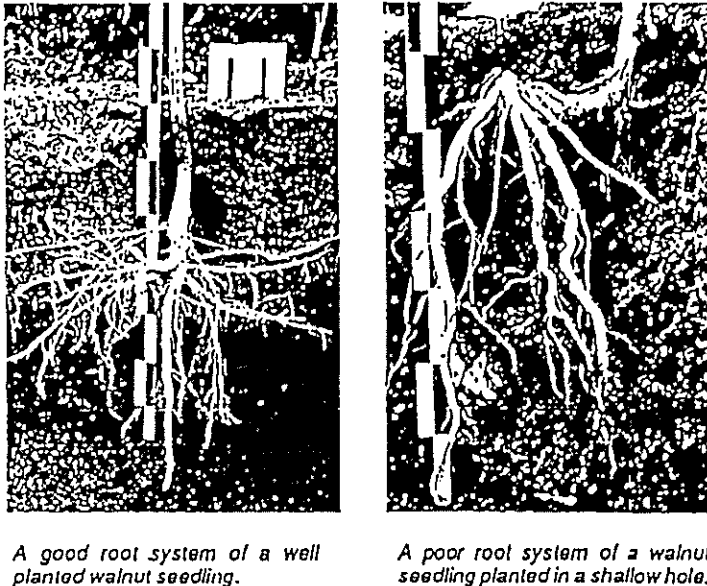


Figure 6.3 Compare the good root system of a seedling planted correctly (left), to the awkwardly formed roots of the seedling planted incorrectly (right).

Plantations may be established by mechanical or hand planting, or by direct seeding. The decision to employ either planting method, or a combination of the two, will be governed by the topography, plantation size, soil type, existing trees, drainage, and ground cover of the planting site; the availability of casual labour and machinery; and the cost. In the final analysis, the method which achieves good planting at the lowest cost will be favoured. Managers of established tree farms usually employ both planting methods; mechanical planting for the large open areas and hand planting in areas which are not accessible by equipment, are too stony, or where topography precludes use of mechanical planters.

Machine VS. Hand Planting

Advantages of mechanized planting:

1. Most suited to large, open areas with reasonably level ground and deep, stone free soil.
2. Faster than hand planting by 3 to 4 times (1000 seedlings/ hour with a 3 person crew).
3. Requires minimal supervision to control quality.
4. Requires fewer planters.
5. Usually results in straighter, more evenly spaced rows than those planted by hand.
6. Produces uniform planting.
7. Generally provides very good root to soil contact.

Disadvantages of mechanized planting

1. Higher cost. (Planters may be rented for a reasonable price.)
2. Only handles small seedlings (usually 1- to 2-yr-old hardwoods, and 1- to 3-yr-old conifers)
3. Some mechanical planters may damage the terminal bud of hardwood trees and plant them at an angle.
4. Does not work well in stony or coarse gravel sites, on steep slopes, in heavy clay, or in wet areas.
5. Inefficient in small, or awkwardly shaped areas where considerable time is spent turning around.

Advantages to hand planting:

1. Can plant any size, area or terrain - steep slopes, partially treed, stony, gravel and wet sites.
2. Can plant virtually any size seedling.
3. Not subject to mechanical breakdowns.
4. Can plant for re-filling mortality in existing plantations

Disadvantages to hand planting:

1. More difficult to get straight, evenly spaced rows and uniform planting.
2. Labour intensive.
3. Requires considerable supervision.
4. Slower than machine planting (50 to 200 trees/hour/person depending on experience and terrain).

Machine Planting

For one time planting or in the initial stages of a tree farm or plantation, the owner may find it economical to rent mechanized planting equipment, or contract the tree planting to a custom operator. An agroforester contemplating the purchase of a planting machine should consult silvicultural equipment manufacturers for advice on choosing from the many makes and models available. A common type of planter in southern Ontario consists of a rolling coulter that splits the earth ahead of a trencher which opens the soil to receive the seedlings, as the operator places them. A pair of packing wheels follows, firming the soil around the tree roots as the trench closes. The planter operator is usually seated directly over the packing wheels, providing additional weight to help pack the soil firmly (Fig. 6.4). A slit planter opens the ground to receive the tree and a scalping or furrow planter is equipped with mouldboards (plough blades) and throws a scalp or furrow ahead of the trencher on either side of the row of trees. Slit planters are most suited to planting on cultivated fields, areas with a light sod cover, or sites where vegetation is controlled by pre-planting herbicidal treatment, while furrow planters are used on sites with heavy sod cover where no weed control has been done.



Figure 6.4 A machine planter. (Photo courtesy of OMNR, Kemptville, 1970)

Furrowing, also called mounding, has long been a common method of site preparation for conifer planting and provides some early benefits, including temporary competition control, providing drier microsites in poorly drained areas and warmer soil for a longer root growing season. Trees planted on top of furrows have a slight height advantage over competition. However, if furrows are not properly spaced they can impede wheeled vehicles during mowing and spraying operations and impede foot travel during pruning, shearing and harvesting. Trees should not be planted in the bottom of furrows. The temporary relief from competition seldom compensates for the loss of growth that results from the lower fertility of the subsoil, the loss of the seedlings' height advantage, rodent damage, grass overtopping and the increased danger of flooding and frost damage.

Hand Planting

Several techniques for hand planting bare-root stock are utilized. The method chosen will depend on the soil, but does not matter as long as the result is a well planted seedling. One of the most common methods is wedge planting (Fig. 6.5), in which a wedge of soil is removed, the tree roots are inserted in the hole against the vertical edge and the wedge is replaced. A variation of the wedge method is the T-cut (Fig. 6.6), where a 'T' is cut in the soil with a shovel and a mass of soil lifted out from the top of the T. The seedling is placed in the hole, the soil is replaced and packed firmly. The slit method (Fig. 6.7), where the roots are inserted in a slit made by pushing the handle of the shovel back and forth, should be used only in soils that are

very stony or wet, when it is impossible to use the wedge method. The slit method is vastly inferior to the wedge method as it makes good placement of roots difficult and tends to leave an air pocket at the base of the slit. Air pockets prevent root contact with the surrounding soil and may cause the tree's roots to dry out. A modified slit method avoids this problem (Fig. 6.8). This method is suited to shovel, mattock or dibble planting and does not result in air pockets.

Figure 6.5 The wedge method of tree planting. A wedge of soil is removed, tree roots are spread against the vertical edge, the wedge is replaced and the soil packed firmly.

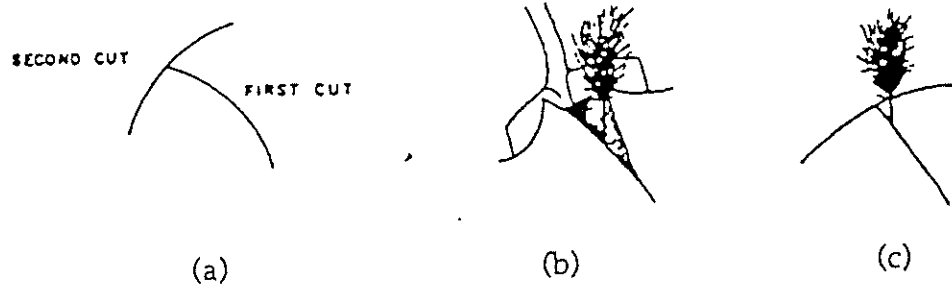
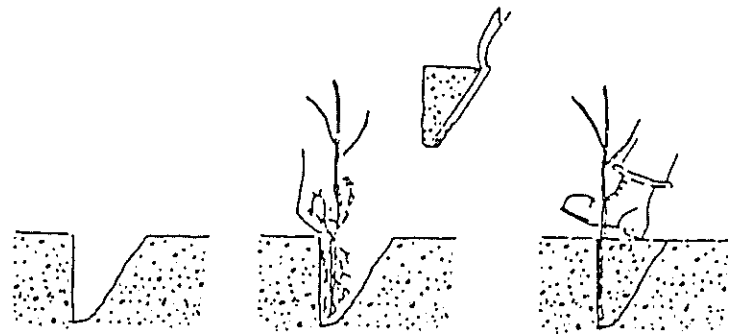


Figure 5.6 The T-cut planting method. Two cuts are made, perpendicular to one another (a). The soil is lifted from the second cut, while maintaining pressure on the shovel handle, and the tree is placed into the slit made by the first cut (b). When the shovel is removed the soil

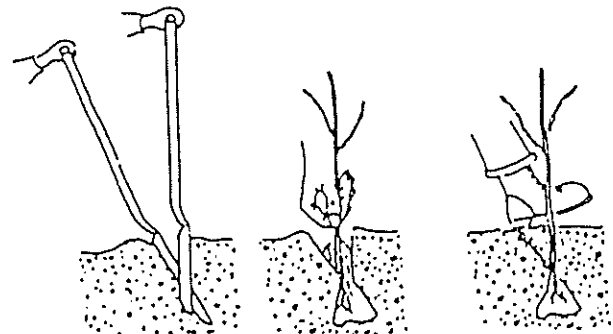


Figure 6.7 The slit method of planting. Note the possible air pocket at the base of the planting hole.

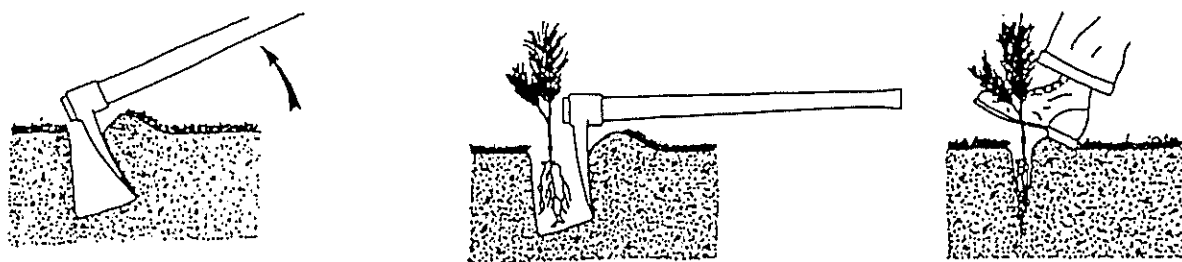


Figure 6.8 The modified slit method is shown with a mattock, but is also suited to shovel or dibble planting. This method does not result in air pockets.

Hand tools which may be used for planting trees are readily available. Some commonly used planting tools are round-mouthed shovels and square spades with either short or long handles, mattocks, and planting bars or **dibbles**. The **tree planting shovel** (Fig. 6.9), a short-handled, round-mouthed spade, is the tool used to plant most seedlings in southern Ontario but is only recommended for small stock. The choice of tool will depend largely on the soil conditions of the planting site, size of seedling, equipment availability and the personal preference of the manager and workers.

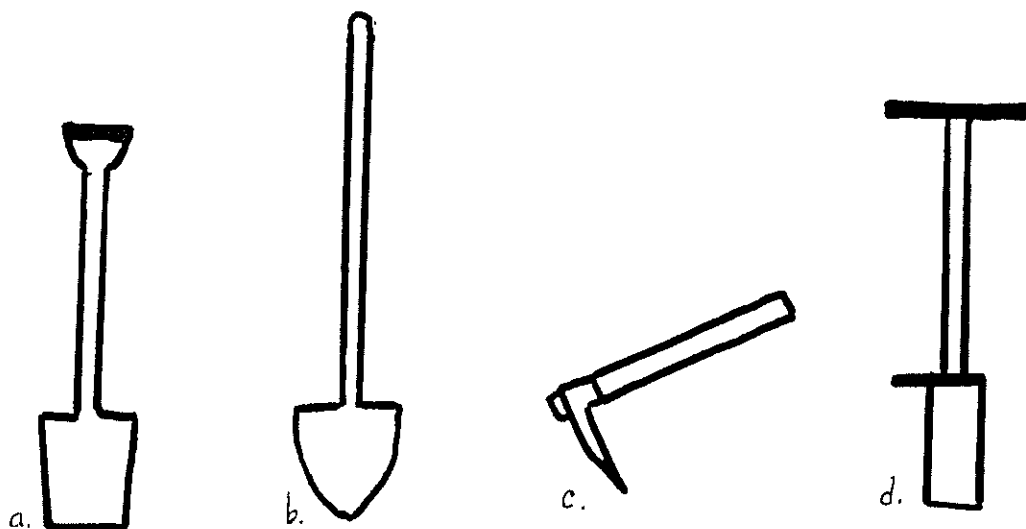


Figure 6.9 a) square spade, b) round mouthed shovel, c) mattock, d) dibble.

The seedlings may be carried in a pail or bucket containing water to keep the root systems moist. Trees should not be crowded in the bucket, because root damage will occur if they are left in water too long. Some workers prefer canvas or plastic planting bags attached to a shoulder harness or belt, which alleviates the task of picking up and setting down the bucket. Such bags allow free use of both hands to handle planting tools. Stock carried in planting bags is kept moist by packing wet moss or peat around the root systems. Packing seedlings tightly into bags or pails often results in damage upon their removal. Only one tree should be out of the bag at a time.

Supervisors should discourage the habit of carrying a number of seedlings in the free hand, as it exposes bare roots to the drying effects of sun and wind.

Supervision of a hand planting operation should include a preliminary training program for workers. The time spent instructing workers and demonstrating proper planting methods is well justified, and will result in improved planting quality. The work of the planting supervisor is simplified if workers fully understand the standards expected before the work begins. While planting costs are important, the rate of production should not be the prime consideration when evaluating the abilities of planters. Not all employees can work at the same speed while maintaining good planting quality. A high rate of seedling survival attained through careful planting is more important in the long run than the number of seedlings planted in a day.

Hand planting with a crew of workers will require the supervisor to devise a method which will ensure establishment of straight rows, and acceptable spacing between and within the rows of trees. Success will depend a great deal on the ingenuity of the planting supervisor and the interest of the workers. Suggested methods include the erection of guide stakes in the field and the use of twine or rope marked at regular intervals for the guidance of the workers. Experienced tree planters often achieve acceptably accurate within-row spacing by pacing the distance between the trees as they plant. The most effective and efficient way to establish a straight line to follow is to either mark a line into the ground or use herbicide to mark rows in the previous year. The latter is also useful since initial competing vegetation is reduced. Straight rows may not be necessary for all types of plantings but they do facilitate easier access for maintenance and harvesting.

Conservation Authorities and the Ministry of Natural Resources will give the landowner advice on planting layout, choice of species, and in some cases will help with actual planting.

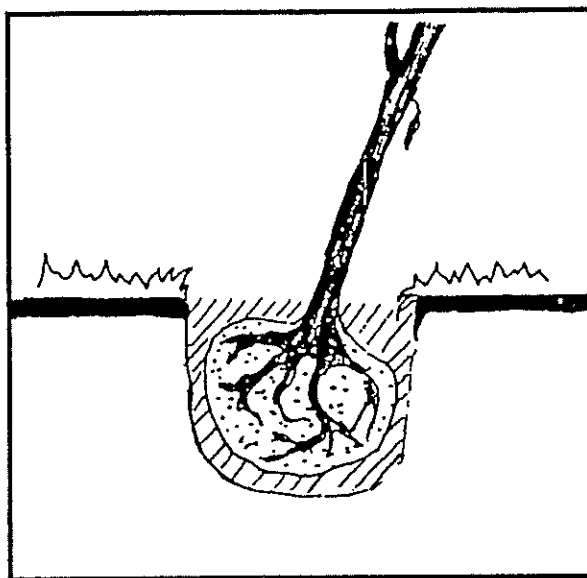
PLANTING LARGE STOCK

Large bare root seedlings or transplants with spreading root systems are most efficiently planted in holes made with a tractor-mounted or hand-held post-hole auger with a bit 25 to 30 cm (10 to 12") in diameter. On clay sites it is important to rough up the sides of the hole to allow roots to penetrate the soil. Otherwise the hole behaves like a clay pot that will bind the roots. The hole should be dug slightly deeper than necessary to allow even spreading of the roots and good aeration of the soil.

The planting season for container stock is not restricted by tree dormancy as much as bare-root stock. It can wait several weeks for planting as long as the soil in the container is kept moist. When planting container stock the packaging should be removed. Fibre pots and burlap are biodegradable, but they do not degrade quickly enough to prevent binding of roots. If the fibre pots are left on, they should be broken in several places to allow roots to escape. Unlike holes for bare root stock, these holes should be dug slightly smaller than the root ball, such that the top of the root ball is slightly above the edge of the hole. This is especially important if the site is poorly drained. The weight of the tree and attached soil will cause it to settle, particularly if the hole was dug too deep and filled back in. This type of stock should be staked for the first

growing season since there may be a tendency for the root ball to shift in the hole causing the tree to lean (Fig. 6.10).

Figure 6.10 Balled stock has a tendency to lean during its first growing season because the soil filled in around the rootball generally cannot be packed tight enough to support it: hence they should be staked.



Trees with stem diameters of several centimetres may be transplanted by specially designed, tractor-operated tree spades that remove up to 1 m³ (1.3 yd³) of soil together with the tree roots. The wire basket used for transporting the tree may be left on, if the top wires are well below the soil surface. Roots will grow around the wire without noticeable damage (Lumis, 1992). Be sure to remove all ropes and wire from around the trunk to prevent girdling.

Transplanting trees from the wild is similar to planting container, or balled stock, except the tree must first be dug up. Trees 1.2 to 3 m (4 to 6 ft) in height and 12 to 25 mm (0.5 to 1") in diameter, with a healthy leader are suitable for transplanting. The tree should be prepared for lifting by driving a spade into the ground about 20 to 25 cm (8 to 10") deep in a circle 30 cm (1 ft) from the tree. This will sever the lateral roots and minimize tearing damage to the remaining roots. Work the shovel downwards and inwards around the tree to loosen it. Use the shovel to lift the tree and soil on to a piece of burlap or plastic, which can be wrapped around the soil and secured at the trunk. The tree is then planted as balled stock.

PLANTING CUTTINGS

Some trees such as poplar and willow are commonly grown from cuttings. Cuttings should be planted vertically with the buds pointing up. They may be pushed into the soil only if the soil is very soft; otherwise, a stick, rod, or dibble should be used to make holes for inserting the cuttings. These holes should be slightly smaller than the diameter of the cuttings to ensure there

are no air pockets around the cutting. The cutting should be planted level with the ground or protruding slightly.

DIRECT SEEDING

Although, on the basis of our current knowledge, planting of nursery-grown seedlings guarantees more consistent success than does direct seeding, the latter method offers the following advantages:

1. The development of a natural root system, which is important in species with pronounced tap roots such as oak (Quercus spp.), black walnut, butternut (Juglans cinerea L.), and hickory (Carya spp.)
2. Elimination of injuries to trees and planters resulting from planting.
3. Reduction in regeneration costs.

Hardwood species, such as ash and maple, are generally unsuitable for direct seeding. Seed from Jack pine is removed from the cone, and seeded directly in reforestation projects in Northern Ontario. Species with large seeds, such as oak and black walnut, can be seeded successfully. Seed may be collected from just about anywhere, although it is preferable to choose a local source, from healthy well formed trees. Not all seed is viable. While it is difficult to determine if small seeds are good, good nuts will sink in water and can thus be separated from hollow, or diseased nuts which float.

Once seed is collected it must be properly treated before planting. Many tree species require certain conditions be met before the seed will break dormancy and germinate. Species such as dogwood and cherry need the acid found in an animal's digestive tract to weaken the seed coat, while jack pine needs the heat of a fire to release its seeds from the cones. Many species, including walnut and oak require a period of cold stratification. Nuts that are planted in the fall receive the necessary cold treatment naturally, but spring planted nuts must be stored in a cold place over winter if they are to germinate the following spring. Successful seeding requires weed control and seed treated in the appropriate manner for the species.

FERTILIZATION

Many of the nutrients required for initial root development after planting, come from within the tree, since most of the fine root hairs are destroyed during transplanting (Lumis, 1992). Therefore, fertilizer applied at the time of planting may be more beneficial to competing weeds than to the tree. Fertilization later in the season, or in future growing seasons is not usually necessary, but may be beneficial on nutrient deficient sites. If mulch is used for weed control, fertilization may be necessary to compensate for nitrogen deficiencies created by the

biodegradation of mulch. There remains considerable controversy on the effectiveness of fertilizing older hardwood stands.

If fertilizing is going to be done, it should be done only after ensuring adequate weed control and soil testing to determine nutrient deficiencies. In extremely poor soil or very dry conditions, it is beneficial to provide organic matter (peat moss or very well rotted manure) at a rate of 3 to 4 litres (1/4 bushel) per planting spot for large planting stock (Neumann, 1992). Fresh or liquid manure is too high in nitrogen content for young trees.

Some conifers such as Scots pine (*Pinus sylvestris*) are particularly efficient at finding nutrients and grow well on impoverished soils, so fertilization is not necessary. In Christmas tree production, where rich foliage colour and rapid growth are desired, these benefits are traded off with the cost of fertilization and additional pruning and shearing costs. As long as tree growth is satisfactory fertilizer costs are better spent on intensified site preparation, weed control and watering during dry spells.

VEGETATION MANAGEMENT

Weed control is essential to a seedling plantation for the first 3 to 5 years. Good control of competing vegetation will improve tree vigour, cut the time required for a crop rotation, and reduce problems with rodents. Uncontrolled ground cover provides ideal habitat for mice, voles and other small mammals which sometimes girdle the trees in winter. A heavy crop of vegetation suppresses the early growth of young trees by competing for light, moisture and nutrients. Grasses, which are a major component of most planting sites in southern Ontario, compete vigorously with tree seedlings for soil moisture and nutrients. Competing vegetation such as tall grasses and golden rod may bend conifer seedlings to the ground in winter when snow lands and ice accumulates on them. On the other hand, having some weeds may offer protection from sun and drying winds during droughts. Methods of controlling vegetation include using herbicide, cultivating, mulching, mowing, or a combination of these techniques.

HERBICIDES

As discussed earlier in site preparation, herbicides are effective either on their own or in combination with other means of weed control. Unfortunately, many hardwood species are highly susceptible to damage at the application rates necessary for effective control. For example, few species are tolerant to paraquat. Each species has its own tolerance for herbicides. This tolerance is modified by soil characteristics, climate, seedling age, time since establishment, and by the timing and method of application. Herbicides often compound other stress factors such as weather, poor site conditions, and poor planting and storage. To provide the best possible weed control without causing seedling damage, it is most important to apply the herbicides only at the recommended application rates. **READ AND ABIDE BY MANUFACTURER'S LABEL.** Applied properly, herbicides control weeds very effectively, but improper application will do more harm than good. Anyone using herbicides must be certified and fully aware of the danger

of serious damage to crop plants, the environment and their own health. If proper application cannot be guaranteed, herbicides should not be used.

Although many herbicides are currently available and new chemicals are marketed every year, simazine (trade names Princep®, Simaprim® and Simadex®) and glyphosate (trade names Roundup® and Vision®) remain the most useful herbicides in afforestation in southern Ontario. Glyphosate is a contact herbicide, which will injure or kill all vegetation sprayed, so care must be taken to avoid spraying the leaves of tree seedlings. A section of stovepipe mounted on a stick can help shield trees from spray, but the individual spraying must still be aware of where the spray is drifting. Do NOT spray on windy days.

Spraying should start when the weeds are 10 to 15 cm (4 to 6") tall. Spraying at this early stage of growth will require a second application in July to kill the late-emerging weeds. However, if spraying is delayed until the weeds are as tall as or taller than the tree seedlings, it is impossible to spray the weeds without having some spray drift onto the tree leaves, and furthermore, seedling growth will already have suffered from the competition. Simazine is a soil sterilant with 2 to 3 years persistence, which is applied during the dormant season and depends on being translocated down into the soil by rainfall. Its relatively low cost and persistence make it a popular choice, however, it does have limited effectiveness on existing sod or triazine resistant weeds. Caution should be taken, since some species such as poplar and larch are not simazine tolerant.

MECHANICAL CONTROL

When chemical weed control is not feasible or desirable, competition can be controlled by manual or mechanical methods. Hoeing around trees can be effective, but it is not recommended because it does not generally provide adequate control and it often injures tree stems and roots. Roto-tilling and discing are effective methods of weed control, but will damage roots if done too close to the trees. Manually pulling weeds and grass from around trees is effective, but not practical.

Discing or roto-tilling once per month from May to September will keep the area between the rows relatively free from competing vegetation. In the past it was common practice to disc between rows of trees without providing weed control between the trees within rows. Most tree seedlings derive little or no benefit from this treatment. Even with discing between rows, seedlings are generally still surrounded by weeds that physically interfere with their growth and deprive them of moisture and nutrients. Excellent weed control can be obtained by supplementing between-row cultivation with mulch or herbicide treatments within the row.

Mowing

In areas subject to erosion where cultivation is not suitable, mowing may be used to control weeds between rows. It prevents weed species from producing seed, reduces cover for rodents and improves working conditions for pruning and harvesting operations, but has not proven to be a good method of competition control. Applying herbicide, or mulching around trees within rows

is still necessary because mowing may intensify competition by keeping grass in a fast growing, juvenile state and stimulating root growth of weed species.

Mowing may be accomplished with various attachments to a tractor or all-terrain vehicle, or with a brush saw or weed-eater. Many makes and models of mowing equipment suitable for weed control in plantations are available. Great care must be taken not to damage the trees with mowing equipment. Consulting established tree farm managers and studying their equipment will be helpful in deciding what equipment will best meet the agroforester's needs.

MULCHING

Mulching to control weed and grass competition has become standard practice with many vegetable growers. In forest plantations, however, mulches have been applied only experimentally. Aside from controlling competition, mulching traps soil moisture and reduces temperature fluctuation. Unfortunately, organic mulches such as bark, sawdust, peat moss, hay and straw have generally failed to provide weed control for long periods and can lead to nitrogen deficiencies as a result of their decomposition. Mulching on poor soils can be detrimental, as can the accumulation of tree litter, if it can't decompose due to a lack of soil microorganisms. Some mulches also shelter rodents, which may girdle young hardwood trees. A 5 to 10 cm (2 to 4") layer of woodchips is not favourable habitat for rodents and will provide moderate weed control for a couple of seasons (Lumis, 1992). Mulching is usually expensive and may not be economical in large plantations. Mowing or cultivating between rows and mulching only around trees may be a more economical alternative to mulching the whole area.

Plastic film has been used successfully as mulch in windbreak plantings but the cost is too high for use in most large scale plantings. Although well laid plastic film provides effective weed control for several years, the persistence of plastic makes this option environmentally questionable.

A promising new weed control method, especially on land that is subject to erosion, is the replacement of the natural weed cover with legumes. Although clean cultivation has generally resulted in the highest survival and height increment of planted black walnut, seeded herbaceous legumes like hairy vetch (*Vicia villosa* Roth), common lespedeza (*Lespedeza officinalis* [L.] Lam.), sericea lespedeza (*Lespedeza cuneata* Dumont Maxim.) or red clover (*Trifolium pratense*) have significantly improved the growth of black walnut over those in plots with a natural weed cover (von Althen, 1990).

STAKING

Staking a newly planted tree until the root system re-develops in the new location is not necessary in most cases. Seedlings and small bare root stock do not require staking at all. Larger trees do require staking for the first and possibly second growing seasons. Large bare root stock generally do not have the root mass necessary to support the tree, so they will tend to develop a

lean if exposed to strong wind. The clump of soil around large balled stock may shift in the hole over time causing the tree to lean. These situations can be prevented by staking.

Three guy wires or two stakes will provide ample support for any tree. They should be placed far enough from the trunk of the tree so as not to damage the current root system (Fig. 6.11). A piece of nylon webbing, garden hose or rubber from an inner tube, placed at the point of attachment to the tree, will prevent wires from cutting into the tree or rubbing against it enough to damage the bark.

Wires or ropes should be attached as low as possible, between knee and waist height, with enough tension to hold them in place, but not so much as to restrict all movement of the trunk (Lumis, 1992). In a normal tree, movement of the trunk caused by the wind will cause it to develop a taper for strength. If all movement is restricted, as with overly firm staking, or long term staking, the tree will not develop this strength, or worse, may develop an inverse taper. The tree becomes dependent on artificial support and when the stakes are removed the tree may break off in the wind. For this reason supports should only be left for one or two seasons.

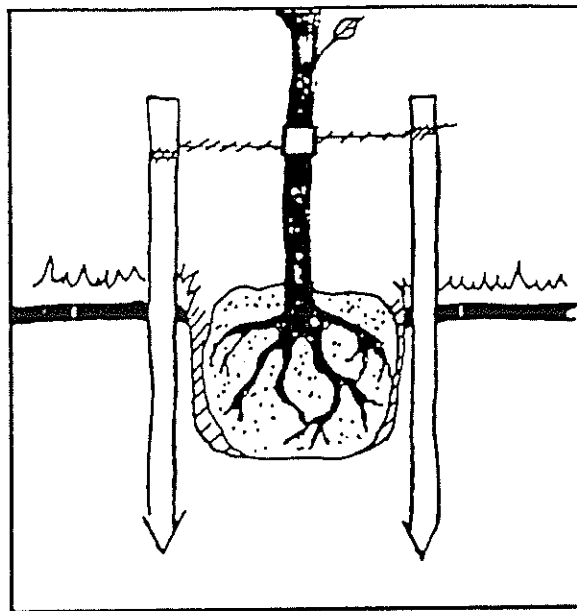


Figure 6.11 Proper staking for balled stock. The stakes are placed out from the root system and nylon webbing protects the bark.

Crown development is usually a reflection of root growth, so if the tree grew well through the growing season, the root system is probably well developed and the supports can be removed. The supports should probably stay for a second growing season if the tree is subject to extremely strong winds, is planted in loose soil, or did not grow very well in the first season. If the stakes are to remain a second season, the attaching wires should be shifted up or down a little to prevent the bark under the rubber and wire from becoming very tender, and to prevent the tree from growing around the wire.

SUMMARY OF STAKING

1. Stake only when necessary -- medium sized stock in loose soil exposed to high winds, or large stock.
2. Attach support to tree as low as possible -- roughly knee high.
3. Place stakes far enough from the trunk of the tree so as not to damage the current root system.
4. Use two stakes or three guy wires .
5. Protect tree from wires with nylon webbing or a piece of rubber. A piece of garden hose or inner tube works well.
6. Allow some movement of the trunk -- do not make support wires too tight.
7. Remove supports after the first growing season, if the tree has developed a good crown. If not, leave supports for another season after shifting the point of attachment either up or down.

PEST CONTROL

Mice, rabbits, groundhogs, porcupines, beaver, grosbeaks, deer, livestock and insects are all capable of causing severe damage to seedling plantations. Fortunately, several methods of control are available.

MICE, RABBITS AND GROUNDHOGS

Only saplings with root-collar diameters smaller than 10 to 13 cm (4 to 5") are damaged by mice, rabbits, and groundhogs, except in years of extremely high rodent populations, or under very unusual weather conditions that prevent rodents from feeding on more palatable vegetation. Mice eat the bark of saplings during the winter, often girdling them. Rabbits gnaw on the bark and browse on the leaves and new shoots. Groundhogs stretch and scratch rather than eat bark, but the effect is the same. They may also gnaw off seedlings close to their burrows and runways. Mice seem to prefer the bark of white ash, sugar and silver maples, basswood, autumn olive, spruce and pine to that of black walnut and butternut seedlings. Rabbits have much the same preferences, except they do not like silver maple. Red oak seems to be a favourite for browsing, as are the fruit and stems of most fruit trees.

Weed Control

The best protection from mouse and rabbit damage is elimination of the weed cover beneath trees. This deprives the animals of shelter and food and makes the plantation a hostile environment for survival and reproduction. Also, elimination of weed competition promotes faster seedling growth so they outgrow the danger sooner.

Tree Guards

Many types of plastic and wire tree guards and shelters are available to provide some protection from rodents and deer for several years depending on the shelter height. Tree guards are tube shaped and go around the stems of young trees, while shelters enclose the entire tree. Mice have been known to nest inside tree guards that they could chew through, crawl under or climb over. Therefore, if tree guards are to be effective they must be tight to the ground and extend above the snow line.

Tree guards also improve seedling growth rate by altering the microclimate around trees. Moisture from respiration is trapped in the guard reducing moisture loss in the summer, and heat is trapped in the spring giving the trees a head start on the growing season. In the winter tree guards protect the trees from ice, heavy snow and wind. Unfortunately, many types of guards may protect the trees too much. Guards that don't allow proper ventilation trap moisture beneath them leaving the bark rather tender. When the guard is then removed the bark is more susceptible to sun scald and frost damage. How severe this problem is varies with the type of tree guard and the species, age and location of the tree. To avoid the problem the protection should be removed gradually by putting holes in the guard or shortening it. Light coloured tree guards are best; dark ones absorb too much heat. Mesh type tree guards are available that provide ample ventilation but small rodents can easily climb them and girdle the tree where the guard ends. The biggest disadvantage to using tree guards is high cost. For plantings with small numbers of valuable trees, the protection provided may be well worth the cost.

Rodenticide

Broadcast application of poisoned grain has been a common approach to mouse control. The most common rodenticide is zinc phosphide. Most agricultural supply stores carry grain or cracked corn treated with zinc phosphide. Although this method is effective in decreasing the number of mice, the relief is generally only temporary because of the migration into the area from adjacent, untreated fields. Furthermore, the exposed, poisoned grain may harm non-target mammals and birds. Feeder stations installed at a 20-m (65-ft) grid spacing (25 stations per ha, 10 per ac) and filled with poisoned grain will provide longer-lasting control and better safeguards (von Althen, 1990). Poisoned mice may still affect non-target predators. The cost of purchase and installation of the stations and the frequency with which the stations must be replenished with grain may make this method unattractive. July is the best month for application of bait, before rodent populations reach their peak in August.

Browsing by rabbits may be controlled by repellents painted on the trees. However, this method is rather expensive, since repellents have to be re-applied frequently and may not be effective. Where by-laws permit, rabbits and groundhogs may be controlled by hunting. Traps, smokebombs or Phostoxin may also be helpful in controlling these populations.

Dogs

A good farm dog is one of the easiest and more effective options for controlling rabbit and groundhog populations.

PORCUPINES

During the winter, porcupines tend to establish themselves in one area of a plantation and feed on the bark of conifers. One porcupine can kill or deform a number of trees in a season. Porcupines may not be so unwelcome in an alder plantation, for example, where they open up the stand to the benefit of adjacent seedlings. Where law permits, trapping or shooting the animals are the usual methods of control.

BEAVER

Streambank plantings of any age are susceptible to beaver damage, particularly if poplar or birch are present. If hungry they will eat jack pine and young hardwoods as well. Beaver will remove preferred species and drown others with water backed up from the dam. If beaver are in the area, trees should be planted that they are not fond of, such as cedar or soft maple. Tar paper, tin or wire on the trunk may help deter beaver. Such barriers must be adjusted annually to prevent stem damage as the tree grows. When beaver become a problem, trapping is the usual solution.

GROSBEAKS

Many Christmas tree plantations have been damaged by the pine grosbeak and to a lesser extent the evening grosbeak. The many small buds produced by Scots pine trees after pruning are a favourite food for these birds during the winter. Removal of the buds does not kill the trees, but results in poor form, which requires corrective pruning and extends the crop rotation. Damage in consecutive years will reduce the overall grade of the crop. Grosbeaks do not follow a predictable migratory pattern, so damage may occur anywhere in Ontario in any given year.

Scare tactics and repellents have failed to protect trees from grosbeaks. However, installation of plastic mesh sleeves on the leaders of the trees does provide effective protection. The sleeves are installed in the fall as a mechanical barrier to feeding and are then removed before growth starts in spring. This is not very practical in many situations, because it is expensive and laborious.

DEER

Deer browsing on leaves and new shoots does not usually kill the tree, but will affect growth and form. Damage is usually greatest at the edge of the plantation, close to natural woodlots which provide shelter for the animals. Repellents and scare tactics are successful in reducing damage from deer as long as other food is available and deer populations are moderate. High fencing is effective in keeping deer out, but it is very expensive. When deer browsing becomes a problem, hunting during the legal season will reduce populations and help minimize damage.

LIVESTOCK

Livestock will compact soil, browse and trample young trees. Unless the plantation has been carefully designed to accommodate pasturing animals on a tightly controlled schedule, they must be fenced out.

PRUNING

The amount and type of pruning trees require depends on the purpose of the planting. Christmas tree plantations require extensive pruning to shape the tree and increase foliage density. Orchards and nut trees require specific types of pruning to encourage fruit and nut production, while areas planted as wildlife habitat or to improve the soil, will require very little pruning. Recognizing when and how much pruning is appropriate is important for any tree/plantation manager.

White and red pine timber plantations are usually spaced close enough to self prune, until the stand is thinned. Their lower branches die and fall off as the canopy closes and blocks the sunlight. Dead branches may be removed at any time from trees in plantations with wide spacings, or conifer species that do not self prune. Removal of these branches increases timber value, without increasing the risk of disease.

Depending on the goals of the landowner, trees in hardwood plantations may be pruned for long, straight, veneer logs, or for large, low crowns more suited to nut, fruit or maple syrup production. Since these goals conflict in plantations such as walnut, where both nut and timber production are wanted, a compromise must be found. Pruning may be carried out periodically until the first 2.75 m or 5.25 m (9 or 17 ft) is pruned, since this will yield 1 or 2 clear 8 ft logs respectively. Prospective agroforestry practitioners should consult established tree farm managers and some of the many reference books available on the art of pruning, to discern how many and which branches to prune.

Branches should be pruned when they are small, generally less than 5 cm (2") in diameter. Small wounds grow over more quickly than large ones. Target pruning is the best technique for pruning as it minimizes the problems associated with pruning and maximizes the benefits (Fig.

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Branches should be pruned when they are small, generally less than 5 cm (2") in diameter. Small wounds grow over more quickly than large ones. Target pruning is the best technique for pruning as it minimizes the problems associated with pruning and maximizes the benefits (Fig. 6.12). Hand pruners are commonly used to cut the branch close, but not flush to the trunk. Never prune more than 1/3 of the living crown. Very little pruning will be required for the first few years, but pruning to raise the crown bottom to desired height is best done early. Suckers sprouting from the tree base should also be pruned off, unless the main trunk has died.

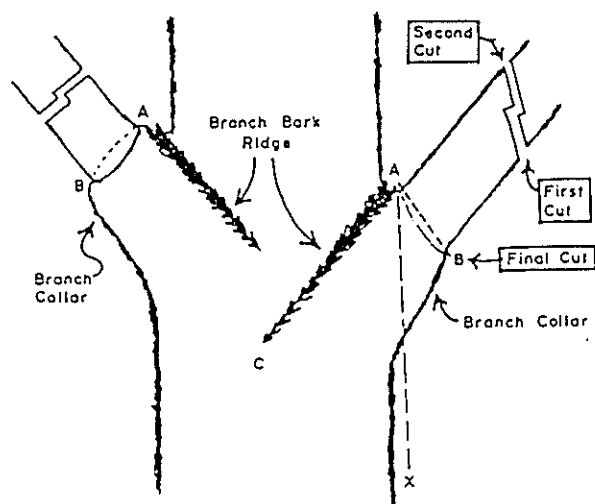


Figure 6.12 Target pruning. (Troket and McGiannes, 1989).

Begin by locating the branch bark ridge. Find target A - outside of the branch ridge. Find target B - the swelling where the branch meets the branch collar. If B is hard to find, drop a line at AX. The angle XAC is equal to the angle XAB. If the branch to be pruned is large, first make a stub cut a few inches from the branch collar. Make the final cut at line AB. Cuts should not be made behind the branch bark ridge or the branch collar. Stubs should not be left.

THINNING

When a new plantation is established, seedlings are usually planted fairly close together to help suppress weed and grass competition, to encourage good form, and to ensure full stocking. As the trees grow, they begin to compete with one another. Some of the trees will become suppressed, some will die, and others will continue to be healthy, but show slow diameter growth. Thinning a stand by removing some of the trees can improve the health and diameter growth of remaining trees.

A function of basal area (m^2/ha) and stand density (trees/ha) makes an excellent indicator of competition among trees. Diameter growth and the depth of the live crown are inversely related to stand density. As stand density increases, the diameter growth of individual trees and the depth of live crown decreases. Although the total basal area growth is approximately the same, it is

divided among more trees. Stand density is controlled by the planting density, survival, and harvesting operations.

Different classifications of thinnings are described in chapter 8. Although they are described here in the context of plantation management, they can be adapted to manage woodlots and forest stands.

REPLACEMENT

Replacing dead trees is not usually necessary in plantations unless trees are widely spaced or survival is low. Dead and very weak seedlings in windbreaks should be replaced to prevent the presence of a gap through which wind would be channelled. Sometimes hardwood seedlings will die back almost to the root collar over the winter and grow up from the root in the spring. These seedlings will often do very well and should not be discarded or replaced. To determine if a seedling is alive, scratch a tiny bit of bark off the trunk close to the bottom. If the scratch appears green, that part of the tree is alive and there is hope for it. This does not apply to conifer. A conifer without needles is a dead or dying tree. Replacement trees should be planted in the manner described earlier in this chapter.

REVIEW

1. The most important factor in the establishment of a successful plantation is matching tree species requirements with climate, soils and drainage conditions of the site.
2. Planting layout and spacing are important points to consider so as not to inhibit growth of trees or cause other land use concerns.
3. The most important step in plantation establishment is **site preparation**, to condition the soil and reduce competition from weeds.
4. Trees should always be planted when buds are **dormant** in the early spring or late fall, and roots should be kept cool and moist to prevent flushing before trees are put into the ground.
5. Trees should be planted to the **root collar** with roots evenly spread and soil packed gently, but firmly about them.
6. Mechanized planting is preferable in large, open areas when a large number of trees are to be planted. Hand planting is advantageous in less accessible terrain and is not subject to machinery breakdown.
7. **Direct seeding** can be used where the development of a natural root system is important or to reduce regeneration costs.

Plantation Establishment and Management

8. **Weed control** is essential for the first 3 to 5 years in a new plantation and can be accomplished with herbicides, mechanical control, mowing or mulching.
9. **Staking** is usually only necessary with medium sized stock in loose soil exposed to high winds, and large stock.
10. Mice, rabbits, groundhogs, porcupines, beaver, grosbeaks, deer and livestock may cause damage to young trees in a plantation. Damage may be controlled through the use of tree guards and shelters, weed cover removal, rodenticides, the presence of a good farm dog, or fencing.
11. **Thinning** may improve the tree crop by removing less productive trees to favour the growth of the dominant, more valuable trees, while at the same time possibly providing a substantial, early boost to the income generated from the plantation.

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APPENDIX A Fact Sheet for Glyphosate

Trade name of herbicide:	Roundup® licensed for agricultural use, Vision® licensed for forestry use.
Common name of active ingredient:	Glyphosate
Manufacturer:	Monsanto
Formulation:	water-soluble liquid
Concentration:	356 g/L of active ingredient (35.6%)
Suppliers:	Roundup® in containers of 1 and 10 L at most Co-op stores and garden centres. Vision® in containers of 10 L from Monsanto Canada Inc., 55 Murray Park Road, Winnipeg, Manitoba R3J 3W2.
1993 price:	\$22/L
Description:	This is a non-selective contact herbicide that kills or injures all plants, including tree seedlings, when sprayed on the foliage. Glyphosate is inactivated in the soil, and therefore does not provide residual weed control. Perennials or unemerged plants arising from underground rhizomes or rootstocks will not be affected by the spray and will continue to grow. Since many annual weeds germinate from seed throughout the growing season, repeated applications may be necessary to control weeds that have germinated since the previous spraying.
Mode of action:	Glyphosate enters plants through the leaves and moves into the root system. Visible effects on most annual weeds occur within 2 to 4 days, but on most perennial weeds they may not occur until 7 to 10 days after spraying. Cold or cloudy weather at treatment time may slow down herbicide activity. Prolonged drought at the time of spraying or rainfall within 6 hours after application may prevent uptake of the chemical and an additional treatment may be required.

- Spray equipment:** Do not mix, store or apply Vision®, Roundup® or spray solutions of these chemicals in galvanized steel or unlined steel (except stainless steel) containers or spray tanks. Use only plastic, fibre glass, aluminum or stainless steel tanks. Spray large areas with tractor-mounted boom sprayers and small areas or spots with backpack or hand sprayers.
- How to apply:** For site preparation and in non-crop areas in which it is desirable to eliminate all vegetation, broadcast the spray mixture over the total area or apply in strips or spots. In areas in which young trees, shrubs or other desirable plants have been planted, either direct the spray away from the desirable vegetation or shield the vegetation from the spray. Never spray on windy days and always avoid drift that might injure or kill desirable vegetation.
- When to apply:** Apply at any time during the growing season as long as the vegetation is tall enough to provide adequate leaf surface to receive the spray. For spring application, spraying should be delayed until the weeds are 10 to 15 cm (4 to 6") tall. The best control of most perennial weeds is obtained when treatment is made in late growth stages, as weeds are approaching maturity (August and September).
- How much to apply:** For large areas, mix 4.7 L of Vision® or Roundup® with 200 to 300 L of water (depending on the size and density of vegetation) for each hectare to be sprayed (½ gal with 20 to 30 gal of water for each acre). For small areas or spot treatments, mix 30 ml (1 fl oz) of Vision® or Roundup® with each 4.5 L (1 gal) of water. The area covered with 4.5 L (1 gal) of mixture depends on the height and density of the vegetation. For best results, wet the foliage uniformly and completely but avoid runoff from the leaf surfaces.

Note: Before using any pesticide product, read the manufacturer's guidelines carefully to determine safe handling procedures, recommended safety equipment, and first aid procedures to use in the event of an accident.

Chapter 7

TREE, FOREST AND WOOD MEASUREMENT

Marnie Benson

To evaluate a forest stand or community, the forest manager must be capable of making both qualitative and quantitative descriptions of the forest. Qualitative descriptions are based on experience and can be highly subjective. Quantitative measurements, on the other hand, are objective, reproducible upon repeated sampling and are subject to critical evaluation. Quantitative data on individual trees, stands and harvested wood products are all important in the proper management of forest ecosystems.

TREE MEASUREMENTS

Measurements on individual trees within the forest stand provide the forester with important information which can be used to take stock of what is present in the stand, or make management decisions concerning individual trees, or the stand as a whole. Two of the most important reasons for tree measurements are to determine wood volume and tree growth rates. Individual tree measurements include **DBH** (diameter at breast height), tree height, depth of live crown and tree age.

DIAMETER AT BREAST HEIGHT

DBH is the average stem diameter, outside the bark, at a point 1.38 m (4.5 ft) above the ground on the uphill side of a tree, because it avoids the root flare. Diameter at this point can be used to calculate a reasonable estimate of wood volume. The easiest way to remember where to measure DBH is to measure where the 1.38 m height is on your body and measure the trees at that point, when standing on the uphill side of the tree of course.

DBH can be measured using a variety of implements. Diameter tapes (DBH tapes), callipers and "cruising sticks" (Biltmore sticks) are usually used but one can also measure circumference with a regular tape measure and divide by 3.14. **Callipers** provide a direct measure of DBH and are simple and quick to use, but are a bit awkward to carry about in the forest. When using a calliper, two measurements are made and averaged (through the long and short axis of the trunk).

Tree trunks are not exactly circular and a single measurement might over or underestimate DBH leading to subsequent errors in volume calculations.

Timber markers often use a **Biltmore stick**, to estimate DBH. In addition to DBH, it also has gradations for estimating tree height, volume and number of 16-foot logs the tree will yield. To determine the diameter of a tree, the stick is held against the tree 25 inches (63.5 cm) from the eye with the left end of the stick at the left side of the tree. The diameter is read where the right side of the tree crosses the stick. Since there is less fiddling around with the instrument, a Biltmore stick is a very quick and accurate way to estimate DBH for timber volume estimates. For other purposes, other methods should be used.

Diameter tapes are popular instruments to measure DBH. They give an accurate measurement since they go completely around the circumference of the tree, accounting for variations in shape of the trunk. The markings on the tape are calibrated so that the diameter reading is read directly from the tape and no calculations are necessary. Where there is a fluted trunk or one where there are dips in the bark, a DBH tape can overestimate DBH because the tape will span across the space. However this shape of tree trunk is difficult to measure with any implement.

TREE HEIGHT

Tree height, in combination with DBH, is required to calculate wood volume in a tree. It is also an indicator of the quality of the site and the vigour of the tree when considered in relation to age and diameter. The heights of small trees can be measured directly with calibrated poles or rods but most trees taller than six metres require a more innovative approach. Heights of taller trees are usually measured with instruments called **hypsonometers**. Numerous hypsonometers have been devised over the years but all are based on either the geometric principle of the relation of the sides of similar triangles (Fig. 7.1) or on the trigonometric principles of the relations between the sides and trigonometric functions of the angles of right triangles (Fig. 7.2). Four common methods of tree height measurement follow. The first three are techniques which utilize hypsonometers and geometric or trigonometric principles. The last two are simple methods that do not require specialized equipment, only some geometric principles and simple calculations. Although costly, hypsonometers usually provide the most accurate tree height estimates when all distances are measured correctly.

Figure 7.1

Application of geometric principle of similar triangles to tree height measurement. EA is the horizontal distance of the observer from the base of the tree. DC is the known height, or length of an object held within the observers' line of view at a known distance (EC). The lengths are then applied to the above formula to determine BA, the height of the tree

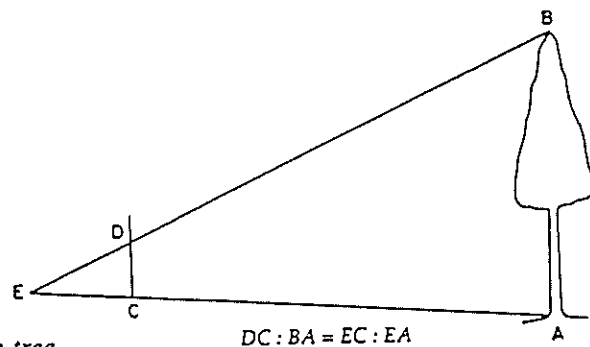
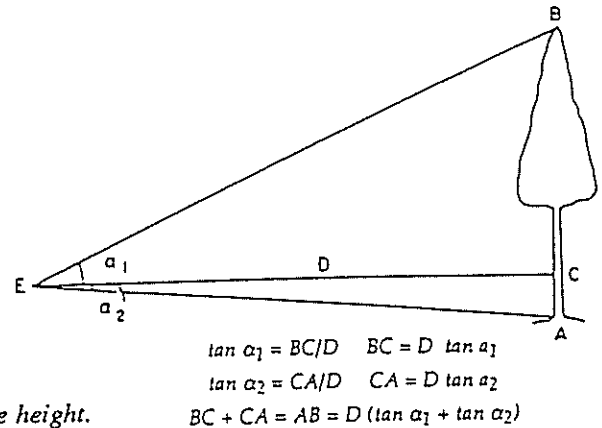


Figure 7.2

Application of trigonometric relationships of right angles to tree height measurement. EC is the horizontal distance of the observer from the base of the tree. BC is the distance from the top of the tree to the horizontal line of site of the observer and CA is the distance from the line of site to the base of the tree. The two added together equal the total height of the tree. The angles α_1 and α_2 are determined with the hypsometer and then used in the above formulas to determine BC and CA and hence the tree height.



a) Using an Abney Level

The topographic Abney level is a hypsometer that is based on trigonometric principles. The Abney level permits the measurement of the angle between a line horizontal to the viewer's eye level and the point above or below that line which is being sighted. By looking through the sighting tube the user can fix a sight upon the point to be measured, adjust the spirit level bubble to the horizontal position and simply read the angle on the arc. With this angle and the measured distance to the tree, the height or depth to the point above or below eye level can be calculated by using trigonometry tangent values as explained in Figure 7.2.

b) Suunto and Haga Hypsometers

Other instruments for making tree height measurements include the Haga altimeter and the Suunto clinometer, which rely on the principles of trigonometry. With the altimeter, the observer sets the scale, sights the pistol-like device on the tree and presses a trigger which fixes the height reading in place until it is released. The instrument indicates height directly for various horizontal distances and no calculations need be done.

The clinometer is the most popular instrument to measure tree heights as it is easy to use, accurate and very compact (a bit larger than a lighter). The observer stands either 15 or 20 metres from the tree and values are read on the corresponding scale inside (20 m scale on the left, 15 m scale on the right). Measurements are made with both eyes open, one peering into the lens at a scale and the other lining up the base or tip of the tree with the indicator on the scale. As soon as the hairline in the instrument coincides with the top of the tree the height can be read from the appropriate scale. Two measurements are made to determine height, one at the base and one at the top of the tree and the figures added or subtracted to get the proper total height measurement. The advantages of the Haga and Suunto are: they are the simplest instruments to use because they require no complex calculations to determine tree height, only simple addition or subtraction, and they are also the most accurate.

c) Merrit Hypsometer

This method utilizes the geometric principles of similar triangles. A "cruising stick" imprinted with a linear scale is held at a fixed distance (25 in; 63.5 cm) from the eye and the observer stands at a specified distance from the tree. It is held vertically with the base of the stick lined up with the base of the tree. The observer glances up the stick to read the tree height where the top of the tree crosses the line of sight. The following ratio is then used to determine tree height:

$$\frac{\text{arm reach (cm)}}{\text{distance from tree (m)}} = \frac{\text{scale interval (cm)}}{\text{tree height (m)}}$$

The Merrit hypsometer is a useful aid for estimating tree heights by log intervals but is not reliable for precise work.

d) Pencil Method

A partner is needed for this method. One person should stand back from the tree a distance greater than the tree's height, i.e., further than the tree is tall. The pencil should be held vertically in front of the eye and moved back and forth, toward the observer, until the top of the pencil is in line with the top of the tree and the base of the pencil is in line with the base of the tree. Keeping it at the same distance from the eye the pencil should be turned horizontally so that the bottom still lines up with the base of the tree. A partner is then directed to stand on a point that is in line with the top of now horizontal pencil and a right angle from the tree. The distance from the partner to the tree is measured thus giving the height of the tree. Figure 7.3 illustrates this method for clarification. The ground should be fairly level for this method.

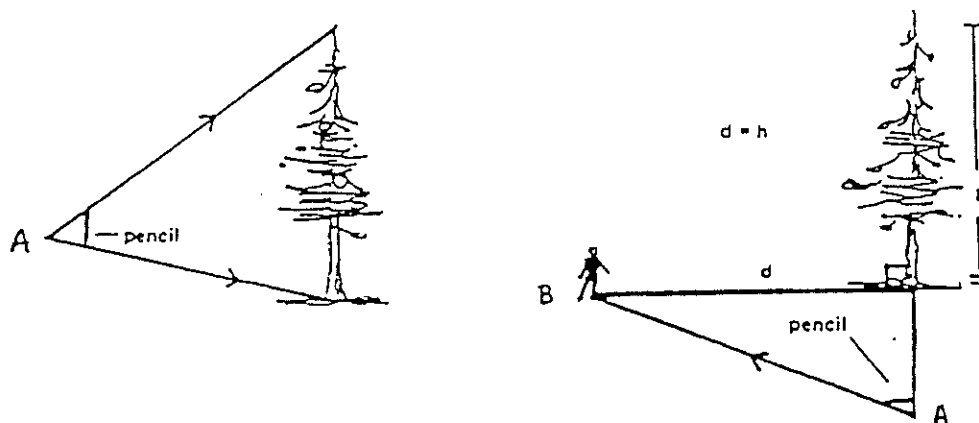


Figure 7.3 An illustration of the pencil method for determining tree height. One observer stands at point A and lines up the pencil with the tree, as in the figure on the left. They then direct their partner to stand at point B where the observer's line of sight crosses the top of the pencil when held horizontally.

e) Multipling a Known Height

The trunk of the tree is marked at a known height, e.g., 2 metres. The worker then stands back from the tree further than the tree is tall. A ruler is held vertically in front of the eye and lined up so that the base of the ruler is in line with the base of the tree and the 2 cm mark on the ruler is in line with the 2 metre mark on the tree. Keeping the ruler in the same position, the worker glances up the ruler and reads the point on it at which the line of sight to the top of the tree crosses it. This will give the tree height in metres since two on the ruler corresponds to two on the tree. Other combinations are possible.

DEPTH OF LIVE CROWN

The depth of live crown refers the portion of the tree that retains living foliage. This is usually determined at the same time as tree height and can be measured in the same manner with a hypsometer by simply subtracting the height of the bare trunk. The proportion of live crown to total height is called the live crown ratio.

AGE MEASUREMENTS

The age of trees is important in determining the rate of growth to date and the likelihood of growth in future. Some trees are very short-lived; others live for a few hundred years. Few trees in Ontario live past 300 years. Three methods of measuring tree age are:

- a) ring count
- b) branch whorls (some species)
- c) height

a) Ring Counts

Most trees grow in diameter each year by adding a layer of wood to the outer edge of the tree, beneath the bark. **Earlywood**, the porous and often lighter coloured wood is produced early in the growing season when moisture is readily available. As things dry up later in the season, growth slows and the wood that is produced, the **latewood**, is denser and usually darker in colour. The earlywood and latewood of one growing season comprise one **annual growth ring**. These can be seen a cross section cut through the stem of a tree. The total number of rings in a tree's stem will tell a person how many years the tree has been alive. They can also be used to measure growth rate, by examining the distance between successive rings; to check tree and area history by looking for distinctive marks at points along its growth profile; or to determine interior condition (rot, etc.).

Logs or stumps

Age of a log or stump is most accurately determined by counting the annual rings. It is suggested that the rings be counted from the centre out, marking every tenth ring with a pen. A magnifying glass may also make counting easier.

To determine the age of a tree, total the number of rings, then add the estimated number of years it took the tree to grow to the height from where the sample was taken. The higher the sample was taken, the more years must be added to the ring count. Although the number of annual rings usually gives a reliable estimate of tree age, it can be a difficult task when growth rings are narrow or non-existent. In shade-tolerant hardwoods with diffuse-porous wood (like sugar maple), tree rings can be difficult to detect even with a microscope. Also, an extra or "false" ring can appear per year in exceptionally fast growing trees, or in years when the growing season may have been interrupted by periods of unfavourable growing conditions, such as drought or defoliation by insects.

Standing trees.

Increment borers are most often used to determine the age of standing trees. They consist of a hollow metal tube sharpened and threaded at one end and equipped with a handle at the other. The borer is screwed into the tree, aiming directly toward the centre of the tree to ensure that the pith is included in the core sample. An "extractor" is forced down the tube and a wooden core is removed when the extractor is pulled out. The rings on the core can be examined and counted to give the age of the tree at the height the core was taken. Again, the number of years it took the tree to grow to that height must be estimated and added to determine total age.

b) Branch Whorls

A **whorl** of branches refers to a ring or layer of branches. These are found commonly in some species (e.g., red and white pine) where the new branches begin from buds only at the tip of the branch. The seasonal height growth of the tree begins with the bursting of the terminal bud, which lengthens to form the leader. At the base of the leader, a circle of branches grow out at the same time, thus marking the height of the tree as it was before the season's growth started. Some species (e.g., spruce) produce some buds at the tip of last year's growth but also down the sides of it. The result is indistinct whorls. Where the whorl is clearly evident it represents one year's growth.

To estimate tree age, count the number of whorls then add the estimated number of years it took the tree to reach the lowest whorl. Evidence of the whorl of branches can be found on some older trees long after the branches have fallen off. This method is generally only useful for fairly young trees, because as trees grow older the bark thickens and the evidence of whorls disappears.

c) Tree Height

Tree height is directly related to tree age and can provide a rough estimate of age. In order to do this however, one must know the growth potential of the tree species, its growth potential on that site and its stage of maturity. On good sites the height growth of trees will be much greater than on poor sites.

STAND MEASUREMENTS

Quantitative variables used to describe or characterize a forest stand are usually arrived at by some method of sampling judged to be appropriate for the particular stand. Since sampling all of a large stand is not feasible, a representative sample is drawn and extrapolated to estimate the characteristics of the whole stand. For example, diameter may be taken from a randomly selected group of trees and the average diameter used as an estimate of the mean diameter of the stand.

The quantitative stand variables or indices most frequently used by foresters are those which yield information concerning (1) the quantity of biomass per unit area (stand density and volume), (2) the quantity of biomass which should be there to meet various ownership objectives (stocking), (3) the species distribution within a stand, and (4) the capacity or potential of the site to produce or generate value (site productivity). Information on these variables helps determine how much wood is in the forest and its value. It is also important in planning and in making management decisions regarding the woodlot.

STAND DENSITY

In forestry, stand density is defined as the quantity of biomass per unit area and is normally measured using a combination of the number of trees and the basal area. Information concerning stand density is important primarily for the indication it gives of the growing conditions of individual trees within the stand. For example, if it is known that a stand on a given site is very dense, it would be safe to assume that individuals within that stand would be competing vigorously among themselves and, consequently, as individuals would be developing at something less than full capacity.

Foresters generally prefer the use of **basal area** per hectare as a more useful measure of stand density. The basal area of a tree is defined as the cross-sectional area of the stem at a height of 1.3 m above the ground (DBH). Basal area per unit area is calculated by summing the individual-tree basal areas of a sampling unit and making the proper conversion for expression on a unit area basis. This conversion results in an expression of density in terms of square feet per acre or square metres per hectare ($1 \text{ sq. ft./acre} = 0.2296 \text{ m}^2/\text{ha}$). Knowing the DBH of a tree,

the basal area (BA) for that tree is calculated as follows:

$$BA = \frac{\pi DBH^2}{(4)(144)} = 0.005454 \times DBH^2 \quad \text{for basal area in ft}^2/\text{acre.}$$

$$BA = \frac{\pi DBH^2}{(4)(10,000)} = 0.00007854 \times DBH^2 \quad \text{for basal area in m}^2/\text{ha.}$$

The basal area per unit area is then calculated by summing up the basal areas of each tree in the sampling area and dividing by the size of the area sampled. Stand BA is highly correlated with the volume and growth of forest stands. Many silvicultural considerations, such as when to harvest or the intensity of thinning, are commonly based on BA measurements. In southern Ontario a mixed hardwood forest with a basal area of 18.5 m²/ha is considered to be in optimum growing condition. As the basal area rises it is desirable to harvest some trees to bring the basal area back to 18.5.

By itself however, the usefulness of BA is limited since it can be made up of many small trees or a few large ones. If the number of stems per hectare or the diameter class distribution is known a reasonable picture of the stand is presented.

TIMBER CRUISING - STAND VOLUME ESTIMATION

For normal operational practices, the methods of estimating the volume of wood in standing forests is termed "**cruising**". Only a sample of the forest is measured and the stand volumes obtained from the survey are extrapolated to estimate the volume in the whole stand. In a timber cruise, trees are usually measured in representative plots or strips, located either randomly throughout a stand or along a transect line. In very small areas, a total cruise can be used where all of the trees are measured. Various plot methods and configurations are described below. To obtain volume estimates of marked timber, the timber markers can tally all the trees, or a representative subsample. These plots vary in shape and size.

In a cruise plot, data is usually collected on individual trees and then used in various computations. these data sheets will have space for collecting important information on each tree, including species, DBH, stem quality, vigour and height.

Wood volume in the cruised stand can be estimated by applying the tree diameter to a volume table or log rule. A volume table is a tabulation that provides the average contents for standing trees of various sizes and species. Volume units most commonly employed are board feet, cubic feet, cords or cubic metres. Volumes may be listed for some specific merchantable portion of the stem only, or for the total stem. With tree height, the number of merchantable logs that might be sawn from the tree can be estimated. Log rules are tabular statements of the contents of logs of specified lengths and diameter. More will be said about log rules and volume calculations in the wood measurement section below. If the landowner's objective is to sell standing timber then the stand(s) will be cruised to determine the merchantable volume that is present. These volume estimates are usually given in board feet and can be determined by using

diameter and a log rule or volume tables. Fixed-radius or variable-radius plots are most commonly used in southern Ontario.

Fixed-area plots

With a fixed-area plot cruise, a number of plots of a certain size representing a predetermined percentage of the stand area are located randomly or along a transect through the woodlot being cruised. Fixed-area plots can be any shape; square, rectangular or circular. The trees are measured on each plot and the data expanded to estimate the characteristics of the entire stand. Circular is most common as only a plot centre and a radius is necessary to establish a plot. Most commonly 0.04-ha or 0.25-acre plots are used.

Diameters of trees in these plots are collected to produce an estimate of volume per unit area (m^3/ha) that is then applied to the whole area for a volume total.

Strip cruising is a type of fixed-area plot where the DBH of all trees within a certain distance on either side of a transect line are tallied and the volume of wood on the area sampled and then on the total area of the forest stand are calculated from these diameter measurements. The line is usually centred upon a measuring tape that is dragged along the ground by a 'compass person' walking in a known direction (compass bearing). The length of the line is measured with the tape. The width of the strip on both sides of the line may be measured with a stick of chosen length, by known arm widths, by measuring tape or by pacing. A tree on the edge of the strip is tallied if it is more than half on the strip; omitted if it is more than half off the strip (Fig. 7.4).

Strip cruises are most often used in very large areas with relatively small diameter trees. They are also used when collecting specific information, like wildlife use or vegetation types, as these data can be easily collected and mapped with a linear plot configuration.

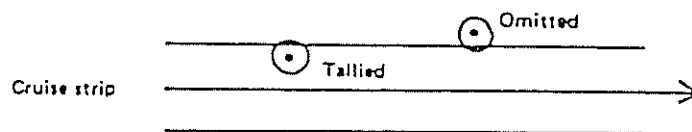


Figure 7.4 An illustration of the strip cruise method for timber cruising.

Variable-radius plots (prism plots)

A variable-radius or prism plot is basically circular, having a different radius for trees of different sizes. It is fast, simple, relatively inexpensive and does not require the location of plot boundaries. The diameters and distances can be looked up on a table to determine whether to measure the tree, but ordinarily an angle gauge or more commonly a prism is used for this. The idea is that it is important to obtain information on larger trees, since they make up a significant and valuable portion of the stand. Since there are fewer larger trees in a stand, it is less likely

that they would be located within a randomly-located fixed-area plot. This method was devised to account for this problem and is widely used where a good estimate of large-diameter sawtimber is needed.

An angle gauge consists of a piece of metal with a hole of a specific width in it. It is held a fixed distance from the plot centre by the timber cruiser, and a nearby tree is centred in the gauge. If the trunk of the tree at DBH is wider than the width of the hole, the tree is measured. If it is smaller than the hole, or there is space between the edges of the trunk and the hole, the tree is not measured.

A prism is used in basically the same fashion except that the prism offsets the image of the stem. If the offset image overlaps with the real image, the tree is measured. If the images do not overlap the tree is not measured (Fig. 7.5).

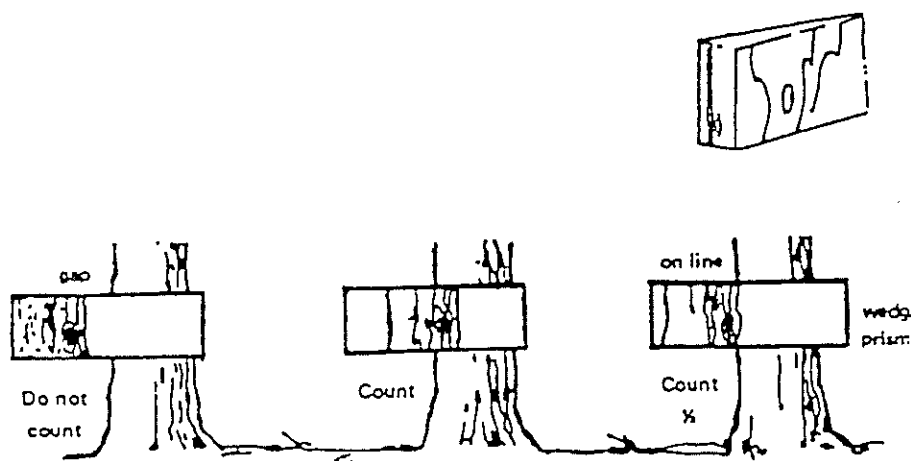


Figure 7.5 Point sampling with wedge prisms. The prism is held horizontally and trees viewed both through and over the prism at the same time resulting in a split image. The figures demonstrate when a tree should be counted, counted as half, or not counted in the sample.

Whether an angle gauge or prism is used, the distance from the plot centre and DBH can be looked up on a table to determine if borderline or obscured trees should be sampled. If a tree is partially obscured, the cruiser can step away from the plot centre to get a clear view of the tree as long as the distance from the plot centre remains the same. If there is a slope in the sampling area the prism should be tilted so that it is at right angles with the ground.

To determine basal area, the number of trees is multiplied by the "basal area factor" (BAF) that is specific for each gauge, prism or table. A BAF 2 (metric) or 10 (english) angle gauge or prism is most commonly used in Ontario but others can be used for specific purposes. If eleven trees were tallied in a plot, the basal would be 22 m²/ha with a BAF-2 prism or 110 ft²/acre with a BAF-10 prism. Generally, prisms are much easier to use than angle gauges, but in dense stands of timber some people prefer angle gauges. As previously mentioned, a fixed-area plot provides a better estimate of smaller trees and a prism plot will provide a better estimate of stands with larger diameter trees.

Volumes of marked trees

In hardwood stands, all of the marked trees in a stand are often tallied to get information on the species, sizes and volumes of marked timber. A **tally sheet** is often used to keep track of this information and keep it organized. Tally sheets often consist of a column of tree diameters, by 2-cm diameter classes, followed by columns for each tree species encountered (Fig. 7.6). Diameters that fall between diameter classes are rounded off to the nearest even number. For example, a tree 15.2 cm in diameter is tallied as 16 cm and 10.8 is tallied as 10 cm. From this information, reasonable estimates of volume, sizes and species are available to provide to prospective buyers of the trees.

Diameter class (cm) (read to next lower number to record)	Species Tally					
	Pr	Pw	Sw	Sb	Po	
12						
14						
16						
18						
20						

Figure 7.6. A sample of the strip cruise tally sheet. Two cm diameter classes are marked on the left and the trees of each different species that fall into each diameter class are tallied. Abbreviations: Pr=red pine; Pw=white pine; Sw=white spruce; Sb=black spruce; Po=poplar.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

GIS systems have been developed as methodology to collect and keep track of information that can be associated with definable areas on maps. The simplest form of GIS is where a map area is divided up into "polygons" according to specific characteristics. For example, a soils map showing the boundaries of different soil conditions could be digitized into a computer and the characteristics of each map unit assigned. This information could then be added to, modified and used for planning purposes.

Starting around 1960, the O.M.N.R. began using a GIS called **Forest Resource Inventory (FRI)** that covers the entire province. The area of the province is divided into polygons according to land use and vegetation. These maps are used for regional planning and as a starting point for on-site forestry activities. For forest stands, the species composition, stocking, age, height, and site quality of the dominant species is given for each map unit (Figure 7.7).

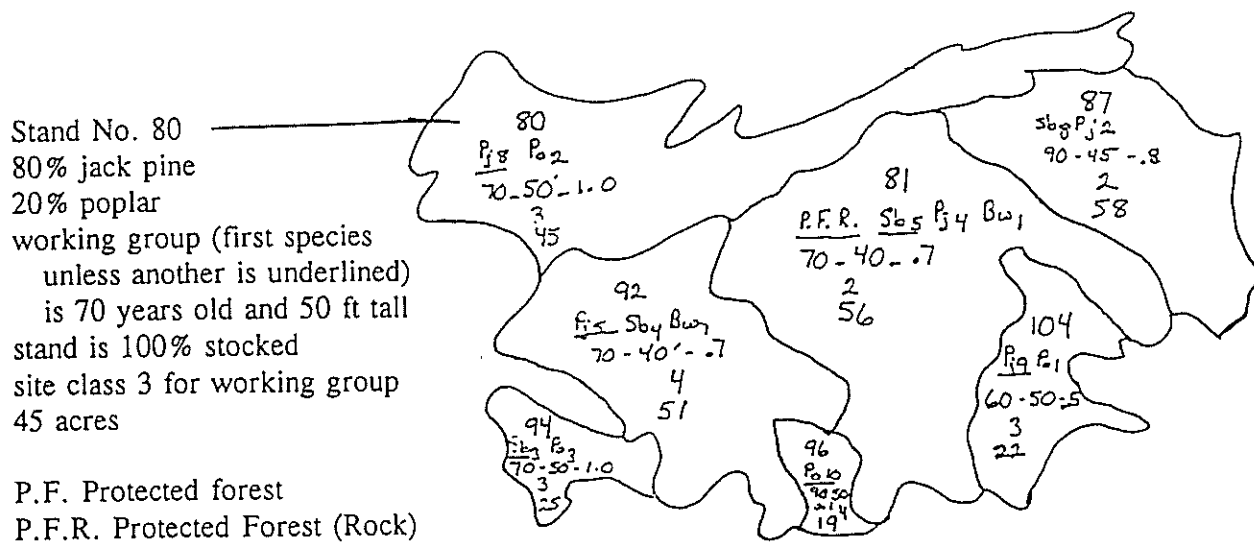


Figure 7.7 Sample F.R.I. map.

Much of the original mapping and much of the updating was done with photogrammetry (aerial photography) and relatively little ground checking. Therefore FRI is notoriously inaccurate on a site specific basis. However it is most appropriate for larger scale uses than stand management. As they work, O.M.N.R. forestry staff constantly collect new information to update the FRI maps.

Remote Sensing

Remote sensing includes any method collecting information from a distance and includes air- or satellite-based photography and other spectral images. Aerial photography is very commonly used for mapping and natural resource management, much as with FRI, with the type of photographs, scale and intensity of sampling varying with requirements of the job. Spectral images, mostly land based are becoming more important in forestry as an inventory method. In spectral imaging, a sensor will record the intensity of a "band" or range of light frequency (e.g., infrared or ultraviolet) within a certain area or cell. When put together these cells will form a picture similar in principle to a television screen or computer monitor. Each band of the spectrum will yield different types of information. For example, the infrared spectrum can give information on tree health and vegetation type. The resolution is variable depending on the satellite, but the best known system LANDSAT, has a resolution of 40-m by 40-m.

WOOD MEASUREMENT

When harvesting one's own woods, as opposed to selling standing timber, marketing the products becomes the landowner's responsibility. Hence it is necessary that the landowner have a good understanding of how wood is measured and on what unit basis it is sold. Marketing wood products (hardwood sawlogs, pulpwood or firewood) profitably, requires a knowledge of

what qualities are required for each product. The knowledge of log specifications, their value to different buyers and current markets, requires experience, and an understanding of log scaling, log grading and log rules.

Scaling is the measurement of forest products - such as pulpwood and sawlogs - after the trees have been harvested. This usually involves measuring log length and diameter to determine the volume or amount of wood that is marketable. Log lengths affect **lumber** value, logging and sawmilling costs, and therefore log values. Since lumber is usually sold in board lengths measured in feet, log lengths typically are specified in even-foot units from 8 to 16 feet, with about 4 inches extra to allow for trimming of rough ends. Log diameters also affect log values. Small diameter logs are more costly to harvest, truck, and saw into lumber than large diameter logs. Hardwood sawmills generally will not accept logs smaller than 20 cm (8 in) in diameter at the small end.

There are a number of methods and units, which follow, that are used in measuring and marketing harvested timber. The method that is appropriate for a particular woodlot owner will depend on what type of wood the landowner is selling and the intended purpose of the wood.

- Stacked Wood (metric and imperial)
- Board Foot Measure (using Ontario Rule)
- Hardwood Log Grading
- Tree Length Scaling
- Mass Scaling (weighing)

STACKED WOOD

Stacked wood is the total amount of **wood, bark and air space** contained in a stack of roundwood as determined by its external dimensions. It may be measured in **cubic metres** (m³) or **cords**. The stacked cubic metre tends to be used by researchers while most of the small industry uses cords. The volume of a pile of wood is obtained by multiplying its height x length x width. One stacked cubic metre is a stack of roundwood (logs) or firewood one metre in length, one metre in height and one metre in width.

The **bush or full cord** is an older method of measuring stacked wood but is still a standard with firewood and other low-end uses of wood to a certain extent (e.g., pallet logs or pulpwood). A cord measures 4 feet high by 8 feet long by 4 feet wide or 128 ft³ of wood, bark and air. A 128 ft³ cord of wood, bark and air contains approximately 85 ft³ of solid wood. Firewood is often sold as a **short cord** or **face cord** which is the same height and length as a bush cord but is only as wide as the length of a piece of firewood. For example, it takes three face cord of 16" firewood to equal a bush cord. It takes four face cords of 12" firewood to equal a bush cord.

Volume in cubic metres:

The volume of a cylinder is equal to $3.14 \times \text{radius}^2 \times \text{length (L)}$. Radius is equal to one half

the diameter (D; measured in cm). Thus the volume of a log in cubic metres is:

$$V = \frac{3.14 \times D/2 \times D/2 \times L}{10,000} = \frac{D^2 \times 0.7854 \times L}{10,000}$$

The volume of the cylinder in cm³ is divided by 10,000 to convert it to m³. Volume tables give the volumes for logs of various dimensions so that calculations are not necessary.

BOARD FOOT MEASURE

The most common measure for hardwood logs in Ontario is the **board foot**. Prices for logs delivered to a mill or sold at the roadside next to a woodlot are usually quoted per thousand board feet (MBF). A board foot of lumber is the volume of wood in a board one foot long, one foot wide and one inch thick (e.g., a 3-ft 2x4 is two BF). To determine the gross board foot volume of a log, the average diameter inside the bark (DIB) to the nearest inch on the small end of a log, and the log length in feet are measured. These measurements are then applied to a log rule, which is a mathematical formula for calculating wood volume. Various log rules exist and all give slightly different volume estimates for the same piece of wood but each has certain advantages for particular situations. Hence it is very important that the woodlot owner know and understand which log rule is being used when prices are quoted and logs are measured in board-foot units. There are three log rules which are commonly used in Ontario: the **International 1/4-inch Log Rule**, the **Ontario Log Rule** and the **Doyle Log Rule**. All hardwood material from Crown lands in Ontario except poplar and white birch, up to and including 18 feet 8 inches in length, has been measured by the Ontario Log Rule. However, some private operators use other log rules which provide different volume content estimates. Volume tables with volumes calculated for logs of various dimensions, by each of the three above log rules appear in Appendices A, B and C.

The International 1/4-inch Log Rule (Appendix A)

The International 1/4-inch Log Rule is based on the mathematical formula:

$$V = 0.199D^2 - 0.642D$$

where V = volume in board feet for a 4-foot section, and

D = diameter inside bark (DIB), in inches on the small end of a 4-foot length.

The formula is changed for log lengths of 8, 10, 12, 14, and 16 feet in order to account for log taper. This log rule is quite accurate, but may result in less lumber being sawn than predicted by log scale. Therefore, an underrun of 5% in actual lumber recovery compared to log scale may occur.

The Ontario Log Rule (Appendix B)

The Ontario Log Rule was adopted as the official rule for determining the volumetric content of logs in Ontario in 1952. The mathematical formula is as follows:

$$BF = (0.55D^2 - 1.2D) \times L/12$$

where BF = board feet,

D = DIB, in inches at the small end of the log, and

L = log length in feet

It applies to logs 4 to 40 inches in diameter and 8 to 18 feet long. Allowances have been made in its development for losses in the wood sawn from logs due to slabs, sawdust, planing, shrinkage and other factors. Log volumes by the Ontario rule tend to be somewhat less than by the International 1/4-inch log rule.

The Doyle Log Rule (Appendix C)

The Doyle Log Rule is based on the mathematical formula:

$$V = (D-4)^2 \times L/16$$

where V = volume in board feet,

D = DIB at the small end of the log in inches, and

L = length of log in feet

It is especially inaccurate on small logs because of its excessive allowance of 4 inches for slabs and edgings. The Doyle rule under scales log volumes for small diameter logs. For these logs it provides an overrun of lumber sawn in comparison to volume of logs scaled. This tends to compensate the sawmill business for the inefficiencies of handling small logs; and in some cases motivates loggers and woodland owners to leave relatively small sawtimber trees to grow. In general, the under scaling of logs increases as log diameters decrease from 23 inches to 8 inches. Also, for the same diameter logs between 8 and 23 inches, 16-foot logs are under scaled about 5 to 15% more than 8-foot logs when comparisons are made with the International 1/4-inch log rule. Therefore it is advantageous to sell 8-foot logs rather than 16-foot logs when the Doyle Rule is used, if the buyer permits. From a forest management standpoint, the Doyle rule sometimes is considered a disincentive to harvesting small diameter, immature trees.

Scaling sticks used by the scaler are like metre sticks with a handle at one end and a plate at the other. In Ontario, board foot volumes based on the Ontario Log Rule for wood 16-feet long are marked on the scaling stick for each 2-cm diameter class. Hence, the volume of a 16-foot log can be obtained by simply reading off the volume estimate when measuring the log's diameter with the scaling stick. Diameter measurements are taken at the small (top) end since the diameter here sets the limits on what can be sawn from the log as lumber.

If a log is straight and free from defects, the gross scale (as read from the scaling stick) is also the net volume. From the standpoint of log scaling, defects include only those imperfections that will result in losses of wood volume in sawing the log. Imperfections affecting only log quality or grade are not regarded as **scaling defects**. Making scale deductions for log defects is basically a matter of determining the type and extent of the defect and computing the board foot volume

that will be lost as a result. Methods for computing deductions are very complex and will only be dealt with here briefly. Deductions for **interior defects** such as heartrot and hollow logs are made on a volume basis. For **exterior defects** such as sap rot, fire or lightning scars, deductions are made on a percentage basis. If over 2/3 of the board foot volume is defective the log is termed a **cull** and is discarded.

HARDWOOD LOG GRADING

Hardwood logs, except poplar and birch, are scaled in board feet and recorded in one of three **log grades**. These grades are based upon three factors: top end diameter, log position in the tree (butt logs or uppers) and the total amount of contained defect. In general, the higher log grades are free from or have fewer scaling and **grading defects** due to sweep, crooks, knots, surface bumps, and decay in the quality zone (the outer portion of the stem, excluding the heart centre). All of these defects reduce the grade of lumber sawn and therefore lumber value. Holes and decay in the low quality heart centre of a log are scaling defects which reduce log volume but not log grade. In Canada, logs are graded on a scale of 1 to 3, grade '1' being the highest quality logs and '3' the lowest.

TREE LENGTH SCALING

This method is used for those mechanical cutting operations where trees are cut, skidded and piled in tree length form. Scaling may be in cubic metres or mass (weigh) scaled. **Butt diameters**, by tree species, are measured inside the bark in 2 cm classes. Volume data from measured sample trees is then used for a calculation of the volume for the total number of trees on a particular operation or group of operations.

MASS SCALING (WEIGHING)

This is the simplest and most precise method of scaling but it requires the installation of expensive weighing equipment. Conifers, poplar and white birch, grade 3 hardwoods and fuelwood may be mass scaled. The **gross mass** in kilograms of a loaded vehicle is obtained. The **tare mass** (empty weight) of the vehicle is deducted giving the **net mass** of the wood. A percentage deduction is made for bark.

SCALING SUMMARY

METHOD	VOLUMES AND UNITS	OTHER DETAILS
(1) Stacked wood (wood, bark and air)	(a) cords - 128 ft. ³ wood + air, 85 ft. ³ solid wood (see also short cords) (b) cubic metre (m ³) - stacked	Typical cord 4' x 8' x 4'. Scaled on one side of pile. 1m x 1m x 1m = 1m ³ Scaled on one side of pile.
(2) Cubic measure (solid wood volume)	(a) cubic foot (ft ³) (b) cubic metre (m ³)	1' x 1' x 1' 100 ft ³ = 1 cunit 1m x 1m x 1m = 1m ³ Scaled on one side of pile. (Butt and top diameters averaged out).
(3) Board foot measure	Board foot units	Tables provide conversions from log diameters to board foot values for the different lengths.
(4) Hardwood log grading	Board feet (Ont. Rule)	3 grades: Gr. 1 (best) Gr. 2 (medium) Gr. 3 (poor)
(5) Tree length scaling	(a) cubic metres (volume) or (b) kilograms (mass)	Butt diameters recorded by species.
(6) Mass (weighing)	kilograms (kg)	Mass of loaded vehicle, minus mass of empty vehicle (tare weight) gives the net weight of wood, with a % deduction for bark.

REVIEW

1. Quantitative measurements of individual trees, stands and harvested wood are important for the marketing of wood products and the proper management of forest ecosystems.
2. Measurements on individual trees include: diameter, height, age and depth of live crown.
3. Field work is simplified if all measurements are recorded and organized upon a **tally sheet**.

4. **Diameter** can be measured with **tree callipers**, **diameter tape** or **cruise stick**. Diameter tapes give the most accurate readings because they go completely around the circumference of the tree and avoid problems with measuring trees that are not completely circular. Diameter is measured at breast height, (DBH; 1.3 m, 4.5 ft) outside the bark.
5. **Tree heights** are usually measured with **hypometers**, instruments which use the trigonometric or geometric principles of triangles to estimate tree height.
6. **Depth of live crown**, the portion of the tree that retains living foliage is also measured with the hypometer.
7. **Tree age** can be estimated by counting **annual rings**, **branch whorls**, or by measuring height of smaller trees.
8. At the stand level, measurements are taken usually to characterize the stand or estimate merchantable volume.
9. **Stand density** is usually quoted in terms of **basal area per hectare**. Basal area is the cross-sectional area of the stem at DBH.
10. **Stand volumes** are estimated by **cruising** the forest to collect diameter and height measurements. These dimensions are then applied to a **log rule** to calculate wood volume in the stand.
11. Stands may be cruised by one of three methods: **strip cruise**, **plot cruise** or **point sampling with wedge prisms**.
12. The measurement of harvested wood products is termed **scaling**. Wood may be measured by a number of different methods and units including: the **cubic metre** or **cord** for stacked wood; the **cubic measure** (feet or metres) for solid wood volume; the **board foot** for lumber sales and by the **kilogram** for mass scaling.
13. Three log rules are common in Ontario for measuring wood volume by the board foot: the **International 1/4-inch Log Rule**, the **Ontario Log Rule** and the **Doyle Log Rule**. Each has its own particular advantage for certain situations.
14. Hardwood logs in Canada that are to be sold as lumber are **graded** on a scale of 1 to 3 (best to poor).

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Appendix A

Log Volumes in Board Feet by Internation 1/4 inch Log Rule

Diameter (D) in Inches	Log length in feet (L)				
	8'	10'	12'	14'	16'
8"	15	20	25	35	40
9"	20	30	35	45	50
10"	30	35	45	55	65
11"	35	45	55	70	80
12"	45	55	70	85	95
13"	55	70	85	100	115
14"	65	80	100	115	135
15"	75	95	115	135	1160
16"	85	110	130	155	180
17"	95	125	150	180	205
18"	110	140	170	200	230
19"	125	155	190	225	260
20"	135	175	210	250	290
21"	155	195	235	280	320
22"	170	215	260	305	355
23"	185	235	285	335	390
24"	205	255	310	370	425
25"	220	280	340	400	460
26"	240	305	370	435	500
27"	260	330	400	470	540
28"	280	335	430	510	585
29"	305	385	465	545	630
30"	325	410	495	585	675

Appendix B

Log Volumes in Board Feet by Ontario Log Rule

Diameter (D) in Inches	Log length in feet (L)								
	8'	9'	10'	11'	12'	13'	14'	15'	16'
8"	17	19	21	23	26	28	30	32	34
9"	23	25	28	31	34	37	39	42	45
10"	29	32	36	39	43	47	50	54	57
11"	36	40	44	49	53	58	62	67	71
12"	43	49	54	59	65	70	76	81	86
13"	52	58	64	71	77	84	90	97	103
14"	61	68	76	83	91	99	106	114	121
15"	71	79	88	97	106	115	123	132	141
16"	81	91	101	111	122	132	142	152	162
17"	92	104	115	127	139	150	162	173	185
18"	104	117	131	144	157	170	183	196	209
19"	117	132	146	161	176	190	205	220	234
20"	131	147	163	180	196	212	229	245	261
21"	145	163	181	199	217	235	254	272	290
22"	160	180	200	220	240	260	280	300	320
23"	176	198	219	241	263	285	307	329	351
24"	192	216	240	264	288	312	336	360	384
25"	209	235	261	288	314	340	366	392	418
26"	227	255	284	312	341	369	397	426	454
27"	246	276	307	338	369	399	430	461	491
28"	265	298	332	364	398	431	464	497	530
29"	285	321	356	392	428	463	499	535	570
30"	306	344	383	421	459	497	536	574	612

Appendix C

Log Volumes in Board Feet by Doyle Log Rule

Diameter (D) in Inches	Log length in feet (L)								
	8'	9'	10'	11'	12'	13'	14'	15'	16'
8"	8	9	10	11	12	13	14	15	16
9"	13	14	16	17	19	20	22	23	25
10"	18	20	23	25	27	29	32	34	36
11"	25	27	31	34	37	40	43	46	49
12"	32	36	40	44	48	52	56	60	64
13"	41	45	51	55	61	66	71	76	81
14"	50	56	63	68	75	81	88	94	100
15"	61	67	76	83	91	99	106	113	121
16"	72	81	90	99	108	117	126	135	144
17"	85	95	106	117	127	137	148	158	169
18"	98	110	123	134	147	159	172	183	196
19"	113	126	141	154	169	183	197	211	225
20"	128	144	160	176	192	208	224	240	256
21"	145	162	181	198	217	235	253	271	289
22"	162	182	203	223	243	263	284	303	324
23"	181	203	226	248	271	293	316	336	361
24"	200	225	250	275	300	325	350	375	400
25"	221	248	276	302	331	358	386	412	441
26"	242	272	303	333	363	393	424	453	484
27"	265	298	331	363	397	430	463	496	529
28"	288	328	360	396	432	468	504	540	576
29"	313	351	391	430	469	508	547	586	625
30"	338	380	423	465	507	549	592	633	676

Chapter 8

SILVICULTURAL SYSTEMS

Silviculture is the science and art of growing and tending forest crops to obtain more and better timber and other benefits from forests. Silviculture is to forestry what agriculture is to farming and is concerned primarily with practices which

1. maintain a vigorous and productive forest made up of species and timber products best suited for the available markets, and
2. provide for replacement of trees as they are harvested, either by natural regeneration or by artificial forest planting.

When applying silvicultural principles in a woodlot it is important to remember that a forest is a living community and that each member of the community is competing with its neighbour for food, water, light and growing space for its crown. Each tree in the forest is influenced by its surroundings and in return influences its neighbour. Its removal will alter these influences favourably or unfavourably, and thus can have a significant effect on the forest community.

SHADE TOLERANCE

The intent of silviculture is to manipulate the forest so as to encourage the desired species and growth to meet management objectives. Knowledge of the individual species requirements is essential since these factors determine how and under what conditions a tree can become established and grow. One of the most important species characteristics is its **shade tolerance**, or whether it can live and grow in the shade of other trees. Table 8.1 contains a listing of shade tolerance for some forest trees in Ontario. The shade tolerance of desired species must be known so that appropriate conditions can be created to establish seedlings. This is necessary for economic reasons to ensure a continued supply of wood and for ecological reasons to ensure the continued presence of the species in the stand.

Management for intolerant species such as aspen, jack pine, or white birch requires large openings. Species that are intermediate in tolerance, like ash, oaks, and white pine will regenerate effectively in the medium-sized openings created when several large trees are cut. Seedlings of shade tolerant species like hemlock, sugar maple and beech will become established and grow under very low light levels, and prosper in small openings created when single large trees are cut. Most tolerant and intermediate species will also regenerate in large openings.

Table 8.1: Shade Tolerance Eastern Canadian Trees

Very Tolerant		Shagbark Hickory	<i>Carya ovata</i>
<i>Conifer</i>		Swamp white oak	<i>Quercus bicolor</i>
Eastern hemlock	<i>Tsuga canadensis</i>	Sycamore	<i>Platanus occidentalis</i>
<i>Broad-leaved</i>		White elm	<i>Ulmus americana</i>
American beech	<i>Fagus grandifolia</i>	White oak	<i>Quercus alba</i>
Big shellbark hickory	<i>Carya laciniosa</i>	Yellow birch	<i>Betula alleghaniensis</i>
Blue beech	<i>Carpinus caroliniana</i>		
Flowering dogwood	<i>Cornus florida</i>		
Mountain maple	<i>Acer spicatum</i>		
Persimmon	<i>Diospyros virginiana</i> L.		
Striped maple	<i>Acer pensylvanicum</i>		
Sugar maple	<i>Acer saccharum</i>		
Tolerant		Intolerant	
<i>Conifer</i>		<i>Conifer</i>	
Balsam fir*	<i>Abies balsamea</i>	Eastern red cedar	<i>Juniperus virginiana</i>
Black spruce	<i>Picea mariana</i>	Jack pine	<i>Pinus banksiana</i>
Eastern White Cedar	<i>Thuja occidentalis</i>	Pitch pine	<i>Pinus rigida</i>
Red spruce	<i>Picea rubens</i>	Red pine	<i>Pinus resinosa</i>
<i>Broad-leaved</i>		Scots pine	<i>Pinus sylvestris</i>
Basswood	<i>Tilia americana</i>	<i>Broad-leaved</i>	
Black gum	<i>Nyssa sylvatica</i>	Black ash	<i>Fraxinus nigra</i>
Black maple*	<i>Acer nigrum</i>	Black cherry	<i>Prunus serotina</i>
Hop-hornbeam	<i>Ostrya virginiana</i>	Black walnut	<i>Juglans nigra</i> L.
Manitoba maple	<i>Acer negundo</i>	Bitternut hickory	<i>Carya cordiformis</i>
Red/Green ash	<i>Fraxinus pennsylvanica</i>	Butternut	<i>Juglans cinerea</i> L.
Red maple	<i>Acer rubrum</i>	Chinquapin oak	<i>Quercus muehlenbergii</i>
Red mulberry	<i>Morus rubra</i>	Honey-locust	<i>Gleditsia triacanthos</i>
Silver maple	<i>Acer saccharinum</i>	Kentucky coffee-tree	<i>Gymnocladus dioica</i>
Slippery elm	<i>Ulmus rubra</i>	Mockernut hickory	<i>Carya tomentosa</i>
		Pecan	<i>Carya illinoensis</i>
		Sassafras	<i>Sassafras albidum</i>
		Speckled alder	<i>Alnus rugosa</i>
		Tulip-tree	<i>Liriodendron tulipifera</i>
		White ash	<i>Fraxinus americana</i>
		White birch	<i>Betula papyrifera</i>
Intermediate		Very Intolerant	
<i>Conifer</i>		<i>Conifer</i>	
Eastern white pine	<i>Pinus strobus</i>	Tamarack	<i>Larix laricina</i>
Norway spruce	<i>Picea abies</i>	<i>Broad-leaved</i>	
White spruce	<i>Picea glauca</i>	Balsam poplar	<i>Populus balsamifera</i>
<i>Broad-leaved</i>		Black locust	<i>Robinia pseudoacacia</i>
Black oak	<i>Quercus velutina</i>	Eastern Cottonwood	<i>Populus deltoides</i> Bartr.
Bur oak	<i>Quercus macrocarpa</i>	Large-tooth aspen	<i>Populus grandidentata</i>
Chestnut	<i>Castanea dentata</i>	Pin cherry	<i>Prunus pennsylvanica</i>
Hackberry	<i>Celtis occidentalis</i>	Trembling aspen	<i>Populus tremuloides</i>
Pignut hickory	<i>Carya glabra</i>	Willows	<i>Salix</i> L.
Red oak	<i>Quercus rubra</i>		
Rock elm	<i>Ulmus thomasi</i>		

* Shade tolerance varies

REGENERATION

An important part of forest management is regeneration. Management decisions made reflect and affect stand species composition, genetic source of new trees, stand density, management objectives, and the period required for establishment. Some of these decisions pertain directly to the new trees, while others control growing conditions such as light intensity, competition, nutrient availability, and/or moisture availability.

The two basic types of regeneration are artificial and natural. Artificial regeneration includes planting seeds, seedlings, or cuttings. Jack pine is often seeded directly by dropping cones from an airplane on to a cleared site with exposed mineral soil. This method is more cost effective than planting seedlings and relatively successful. Most other species do not grow as reliably from seed, and are more often planted as seedlings. Hybrid poplar, willows and cottonwood all grow very well from cuttings, which are less expensive and easier to store than seedlings. All forms of artificial regeneration are more expensive than natural regeneration.

Natural regeneration includes coppice growth, young seedlings already present on the site, and trees that grow from naturally occurring seed. Oak and birch commonly grow from stump sprouts, while aspen and beech develop from root sprouts. One of the most desirable forms of regeneration occurs when seedlings already present on the site are of an appropriate species and survive the harvesting process. Under these circumstances seedlings have good root systems, have a head start on any competition, and cost nothing to establish. Many trees produce seed that will remain dormant in the soil for considerable time. If plenty of good seed is already on the site, planting may not be necessary. Unfortunately, if a site is abandoned it will often be taken over by undesirable species, unless some form of artificial regeneration is used.

MANAGING THE WOODLOT

Whatever its purpose, managing a woodlot properly will limit stress on the trees and provide conditions for good tree health and growth. With that in mind, some important objectives of good woodlot management are noted as follows:

1. To provide sufficient high-quality growing stock and to keep the trees healthy and productive in order to maximize financial returns.
2. To prevent the harvesting of crop trees before they reach their most useful and valuable size.
3. To minimize damage to soil, young growth and uncut trees during harvesting operations.
4. To protect the woodlot from fire, grazing and other damage.
5. To enhance wildlife habitat and tree species diversity
6. To provide for soil and water conservation, aesthetic, and recreational requirements consistent with the landowner's personal objectives.

SILVICULTURAL PRESCRIPTION

When a management activity is considered (usually a cut of some sort), either because it has been scheduled in a management plan or for other reasons, advice should be obtained from a forester or forest technician and the woodlot evaluated. If an activity is advised, a **silvicultural prescription** should be prepared that describes the current condition of the woodlot. This prescription should include the following:

1. Objectives for the activity
2. Percentage of basal area to be removed
3. The species, sizes, quality and crown position of trees to be marked for harvest
4. The probable response of the woodlot to the cut, in terms of tree growth, stand dynamics, economics and wildlife habitat

The two major components of a silvicultural prescription are planning and inventory. Some factors that are important in these areas are listed below.

Planning

1. **Landowner Objectives:** Define what the landowner wants as well as the objectives of the consulting forestry organization (e.g., aesthetics, wildlife, money, recreation or some combination). Both party's objectives can probably be met using different combinations of silvicultural tools (e.g., individual tree selection/group selection prescription). Good forest management combines different objectives so that one land use does not exclude other uses of the forest.
2. **Stand History:** Past land use can have a significant affect on current stand conditions. For example, an old-growth stand with a high beech component, little understorey and no stumps could be a result of past high-gradings and cattle grazing. This site might have a different species composition if not for the stand history. The silviculturist's interest might be in how the stand could be manipulated to change the species composition.
3. **Silvical Characteristics:** The growth habits of the trees on the site, the identification of species that may grow well on the site and the ease of regenerating the various species, are all affected by stand history, site potential, and what changes in the stand are expected from a particular silvicultural prescription.
4. **Other Concerns:** Marketability and value of products from harvest (present and future cuts) and the profitability of the current harvest are important. Operational characteristics of the woodlot limit what type of equipment can be used and what times of year harvesting may be done. Such characteristics include the size of the tract, access to the stand for trucks and equipment, and soil and site conditions as they affect or limit operations. It is also important to consider the present value of the wood products compared to the potential damage to the residual stand or the forest community.

Inventory

1. **Species Composition:** What tree species make up the forest, and in what proportions.
2. **Mensurational Information:** Tree diameter, basal area, heights, depth of live crown, stem density and age are important parameters of stand vigour, and tree growth and health.
3. **Stand Structure:** The arrangement of tree species and crown classes within the different strata and compositional changes between strata.
4. **Condition of Trees:** Health, vigour and quality of the trees in the stand are often related to size and crown position. For example, if the trees in a dominant crown position are large and defective it would be suggested that some of them be removed for several reasons: a) to make room for healthy vigorous trees in the understorey; b) the chance of large trees dying or being blown over before the next cut is fairly high; c) if left, a large defective tree will become a larger defective tree or die, so it makes sense to replace the poor tree with trees that have a greater chance of surviving and accruing value. On the other hand if the landowner is interested in promoting wildlife habitat, some of these large defective trees should be left standing to provide shelter and food sources for a variety of forest dwelling animals.
5. **Site Conditions:** Topography, soil textures, soil drainage and nutrient information are important not only for site capability for tree growth, but also for suitability of the site for harvesting equipment and for dictating the time of year that harvest should take place.
6. **Site Potential:** The potential of the site for growing trees of species other than those in dominant positions in the stand. For example, if a stand is occupied by low quality sugar maple and hophornbeam (ironwood), the landowner might be interested in what the potential productivity of the site would be for red oak. This potential would depend upon soils, climate and other geographical features.

STOCKING

Stand density is related to the number of trees per hectare and tree basal area. It is an excellent indicator of competition, and is controlled by the planting density, tree survival and type of thinning. Diameter growth and the depth of the live crown are inversely related to stand density (i.e. as stand density increases, the diameter growth of individual trees and the depth of live crown decreases). Although the total basal area growth of the stand will be the same, it is divided among more trees. For example, a stand with basal area of 100 m²/ha may contain 1000 trees with an average basal area of .1 m², or 100 trees with an average basal area of 1 m².

STAND IMPROVEMENT/ THINNING

Young, even-aged stands and poorly-managed woodlots may require some form of improvement cutting or thinning to favour the growth of more valuable trees. The objective of an improvement cut is to benefit the growth of the trees with the greatest productive potential by removing nearby competing trees and those with little productive potential. Improvement cutting refers to a wide range of interventions ranging from precommercial thinnings of saplings in plantations to logging in woodlots with a high proportion of poor quality trees.

An improvement cut or thinning is used to control the growth and form of desirable trees, not to maximize current income. If a woodlot is managed to produce sawlogs, thinnings would tend to leave tall, vigorous trees with high value wood. If management is for syrup production, sugar and black maples are favoured. Sugarbushes are grown at lower densities (number of trees per hectare) to encourage diameter growth and large crowns. Improvement cuts in these situations tend to leave fewer trees than would be left if the stand were being managed for another purpose. When managing for wildlife, trees that provide food, shelter, or habitat diversity are favoured.

When new plantations are established, young seedlings are usually planted fairly close together to help suppress weeds and to ensure full stocking. Hopefully, the newly planted seedlings survive the isolation stage of competition, where they depend on their individual ability to derive resources from the site and compete with ground vegetation. Following the consolidation stage, where the crowns of the trees begin to touch, the trees begin to compete among themselves. This active competition encourages height growth, but limits diameter growth. Lower branches become shaded out, and hopefully die and drop off to reduce the size and number of knots produced. When trees become too crowded the stand requires thinning.

A thinning is made in an immature stand for the purpose of improving the growth and form of remaining trees, and improving the species composition of the stand. The idea is to maintain sufficient competition to encourage good form and height growth, while reducing it enough to improve diameter growth. Species composition is improved by removing trees of undesirable species. This increases the percentage of favourable trees and gives them more room to grow.

In an older established woodlot, an improvement cut is required when tree quality has been degraded by poor management practices such as high-grading, or when the proportion of low-value species in the stand is too high. In an improvement cut, the trees removed will be a) trees with poor form or stem defects, b) trees of low-value species, c) trees that compete with vigorous "crop trees", and d) high-risk trees that may die or be damaged before the next harvest. In cases where two desirable trees are competing intensely, one may have to be cut to encourage the full development of the other. In very poor quality woodlots, it is important not to take out too many trees at once, which would leave the stand exposed and subject to windthrow.

Windthrow is also a common problem in conifer plantations that have been left too long without thinning. Jack and red pine stands tend to have little genetic variability in traits affecting growth. Little opportunity exists for one tree to out compete another and the stand stays fairly uniform and stagnates. If such trees are not thinned, they become tall and slender such that they require the support of those around them to keep from breaking off in the the wind. Conifers planted at a spacing of 2 m by 2 m (6.5 ft x 6 ft.5) may be ready for a first

thinning when they reach about 8 to 10 m (25 to 30 ft) in height. However, the timing of a first thinning depends on stand density, tree species, site quality, economics and objectives.

Hardwood stands are not as subject to stagnation as jack pine and red pine, because they tend to contain more species diversity and more genetic diversity within species. When the stand becomes crowded, some trees will dominate, while others will die out, or hang back until space becomes available. Although the dominant and co-dominant trees grow faster than any other trees in the stand, none will show good diameter growth if they are actively competing. Thinning releases the remaining trees, which permits rapid diameter growth, and improves tree health and vigour.

Different ways that thinnings are classified and different methods of thinning are described below. Although they are described here in the context of plantation management, what is said also applies to management of woodlots and forest stands, especially those that are even-aged.

Pre-commercial vs. Commercial Thinnings

A pre-commercial thinning is one where none of the trees or wood are sold. Normally the trees are cut and left in the bush. Precommercial thinnings are a significant cost but are conducted to control tree form, control species composition and to maintain tree health.

A commercial thinning is one where there is revenue from the sale of wood or trees from the thinning. It does not matter if there is a profit (sales are greater than cost), it is a commercial thinning if there is some revenue. Revenue includes the salvage of cut trees for Christmas trees and wood sales for fuelwood, pulpwood or sawtimber.

These terms can be a bit confusing when a contractor is allowed to salvage material and reduce charges to a landowner. The landowner does not see any of the revenue, but it has reduced the cost of the thinning. Therefore, the landowner may consider it a precommercial thinning, but technically it is a commercial thinning. Different types of thinnings can be combined in an operation. Any type of thinning described below could be considered either precommercial or commercial.

Mechanical Thinning

A mechanical thinning is one where trees are removed *en masse* to reduce density; without regard to individual trees. Trees are thinned only on the basis of their spacing without regards to their size, species or quality. After a mechanical thinning there are likely to still be the same proportion of bad trees as were there before, but the vigour and rate of growth of the trees that remain will be much improved. The first thinning of a plantation is often mechanical as the trees are not particularly valuable and the main concern is to reduce density at a minimum cost. In southern Ontario the first thinning of a conifer plantation is often the removal of every fourth row of trees or 25% of the basal area. Another example of a mechanical thinning of a plantation is where every other tree in a row is removed. A mechanical thinning could be conducted with a mower or bulldozer cutting strips through a plantation.

Thinning From Below

A thinning from below or "French" thinning is where the overtopped and low vigour trees are removed from the stand. In a thinning from below, all suppressed trees and many of those in the intermediate crown class are removed from the plantation. This process derives some revenue by anticipating mortality as most of these trees are likely to die before the rotation age anyway. This type of thinning does little to reduce competition in the overstorey. The trees removed from the understorey are using few resources and do not compete significantly with the canopy trees.

Crown Thinning

A crown thinning is one in which trees are removed from the co-dominant and dominant crown classes in order to improve the growth and form of the most vigorous trees in the stand. Spacing, species form and growth potential of the trees are considered when deciding which trees to cut or leave. As the value and growth potential of species is different on a particular site, there will be a hierarchy of preferred species. For example, a red pine may be cut and a white pine left on a calcareous site because red pine often declines in mid-rotation on those sites. A crown thinning gives greatest control over the residual stand but is relatively expensive to carry out as it requires some skill in determining which trees should be left or thinned. A thinning operation can include a combination of a thinning from below and a crown thinning.

Crop-tree Thinning

In a crop-tree thinning, a relatively few "crop" trees are selected and only trees that compete directly with the crop trees are thinned. For example, 250 crop trees could be selected in a hectare of plantation and the thinning crew given instructions to cut any tree touching the crown on two sides of each crop tree. By itself, a crop-tree thinning can be used to reduce the cost of a pre-commercial thinning. Essentially, a crop-tree thinning is a cheaper or less intrusive way of getting the benefits of a crown thinning.

Cleaning

A cleaning is where undesirable species are removed from the plantation. These can be conducted manually (with a saw) or chemically (with herbicides).

Sanitation Cut

A sanitation cut is a salvage operation where defective, diseased, hazardous, unsightly, or otherwise undesirable trees are removed from the stand.

SILVICULTURAL SYSTEMS

There are two basic management strategies that have been developed that result in managed stands with even- or uneven-aged stand structure. In even-aged management the regenerated is composed of trees of similar age. In uneven-aged management, the stand will be composed of trees in all age classes, from seedling to mature trees. These strategies utilize silvicultural systems that result in stands with the appropriate structure. Similarly, silvicultural systems are also classified by the stand structure they are associated with, even- or uneven-aged systems. In practice, the application of some of these systems can be indistinguishable at times.

The appropriateness of a particular management system depends on the tree species, ownership objectives, public use, municipal by-laws and equipment limitations. A number of methods can often be used to achieve similar objectives, so it is the forester or resource manager's job to select prescriptions which will yield a satisfactory result. Two foresters may choose completely different management strategies and neither one could be considered better or worse if the management objectives are met.

Clearcut

A commercial clearcut involves removing all trees of value from an area. The operator, market conditions, and stand access all determine which trees remain standing. Trees left standing are those of no value to the harvester and may include undesirable species, damaged trees, and trees above or below a certain diameter. Commercial clearcuts often result in low quality forests because only low value and poor quality trees are left as seed sources to regenerate the forest. A silvicultural clearcut is where all of the trees, except those smaller than 2.5 cm in diameter (seedlings), are removed. Such clearcuts cost more because they involve removing non-profitable trees; however, they offer greater opportunity for quality regeneration.

With either form of clearcut, the new even-aged stand can develop from established natural regeneration, new natural regeneration, or artificial regeneration (planting or direct seeding). Large openings, such as those created by clearcutting are necessary to regenerate shade intolerant species. Openings of this nature are also required by many bird species. Intermediate and most tolerant tree species may also be managed using a clearcut system, although these species may also be managed using other silvicultural practices.

Clearcutting is the simplest and most economical silvicultural system to administer and regulate. Decisions as to which trees to take and whether a harvest was carried out appropriately are very straight forward. Clearcutting is suited to large equipment and large tracts of land. Lots of manoeuvring space is available for large equipment, and operators need not worry about damaging residual trees. Clearcutting a small woodlot leaves nothing to harvest tomorrow, whereas clearcutting parts of several forest tracts on a rotational basis can be provide timber on an ongoing basis.

Seedtree

A seedtree cut, is basically a silvicultural clearcut with a few high quality trees left standing after the harvest to provide a seed source for natural regeneration. The environmental conditions created for the new stand are similar to those of a clearcut. To help ensure regeneration is from genetically superior stock, the seedtrees are among the best specimens of the species that is desired for the new stand.

Several factors can be considered to help ensure the success of a seedtree cut. Many tree species produce more seed in some years than others, and often these years are in cycles. Seedtree cuts that take place during years of high seed production are more likely to be successful than those done in years of poor seed production. The number of seedtrees left must reflect the species, seed production, location, and timing of the cut.

Seedtree cuts are effective in some situations; however, the value of wood in the seedtrees is often lost because a) wind throw, b) the trees succumb to the sudden stress of being released, or c) it is not economical to return and harvest them. The other risk associated with a seedtree cut is the trees may not produce enough seed, or the seed may not germinate. If this happens, the operator has to pay for artificial regeneration in addition to losing the value of the seedtrees. Due to the potential for unsuccessful regeneration, seedtree cuts must be monitored until regeneration is established. Often it is more reliable to use a clearcut and artificial regeneration than gamble on natural regeneration from seedtrees.

Shelterwood

The shelterwood system is an extremely flexible even-aged system that can have much less visual impact than a clearcut or seedtree system. In its simplest form, (seedcut) to allow more light to penetrate and regeneration to become established. Unlike a seedtree cut, the residual trees can be recovered economically and are not as subject to windthrow. Once satisfactory regeneration is established, the overstorey (the rest of the old stand) is removed (release cut) and the regeneration develops into an even-aged stand.

The original stand may also be removed in more than two stages, with 3 to 10, or even 20 years between entries to the stand. For example, a shelterwood system with more than two entries to the stand could be used where the stand is very dense and a large early cut might open the stand up too quickly and make it subject to wind throw. Also, large openings promote shade intolerant species, which may be undesirable from a management point of view. With a number of entries, smaller cuts could be made, thus avoiding large openings.

The biggest drawback of shelterwood systems is the challenge of administration. A high degree of knowledge is required to make decisions as to which trees to remove in which cut, and how heavy a cut should be, if the system is to successfully meet its objectives. Operators must take care to avoid damaging residual trees, and there is not as much room for large equipment to manoeuvre.

Most species can be managed using the shelterwood system because the overstorey density following the seedcut can range from very low (similar to a seedtree cut) to quite high (as light as a single-tree selection cut). Different overstorey densities will create environmental conditions in the understorey that will allow all but the most intolerant species to regenerate. Additional cuts can be performed to prepare the overstorey and understorey (crown thinnings, thinnings from below and improvement cuts) for the seedcut. In cases where preparatory cuts are used, the shelterwood system will appear very similar to the single-tree selection system (an uneven-aged system).

The shelterwood system has other advantages in addition to its suitability for a wide range of species. In a shelterwood system, the stand is never left in a treeless state, with obvious visual benefits if one is concerned about public reactions from cutting. In fact, stands managed under the shelterwood system can be more desirable from a visual and recreational standpoint than stands managed using uneven-aged systems. The main reason for this is that until the

seedcut, the stand is kept relatively closed, limiting the development of saplings and brush. When the stand is opened up by the seedcut, for a period of time there is a mature overstorey over a layer of young seedlings or saplings; a view that can be quite appealing. In the single-tree selection system, the variety of age classes throughout a stand can tend to obscure the view into a woodlot and may make walking more difficult.

Single-tree Selection

The single-tree selection system is the most commonly used silvicultural system for uneven-aged management. In the single tree selection system, a stand is entered and cut at regular intervals (e.g., 15 years). Trees can be marked in all diameter classes so that the residual diameter class distribution conforms to the inverse-J shaped curve (Figure 8.1) where the forest has many young trees and successively fewer older/larger ones. The single tree selection system requires a great deal of care to work correctly and because of the low level of disturbance at each entry, favours shade-tolerant species like red maple, sugar maple and beech. The selection system *should not* be confused with selective logging or high-grading, where certain, usually high value, species are *selectively* cut out of a stand.

A stand marked using the selection system application could be difficult to distinguish from one using a four-entry shelterwood system. The main difference in principle is that with single-tree selection, there is active management for all age classes and trees from all age classes can be marked, depending on the diameter class distribution. With a shelterwood system, management is geared toward the overstorey until the seedcut. Prior to the seedcut, trees in the understorey, and overstorey that compete with desirable trees are discouraged and usually removed in thinnings.

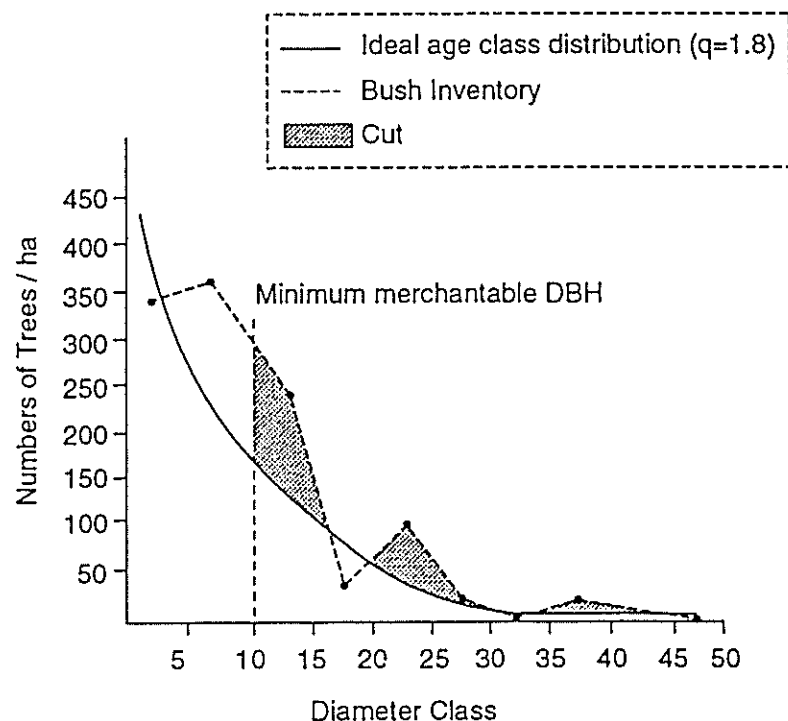


Figure 8.1 J-Curve distribution

Group Selection

Group selection is an uneven-aged system where small groups of trees are removed, creating small openings throughout the stand. These openings are like tiny clearcuts that are large enough for intermediate species to become established and develop before the gap closes. Often, group selections are incorporated with a single-tree selection cut to encourage greater diversity in species and stand structure yet maintaining the uneven-aged distribution. A light application of group selection is very similar to a single-selection cut and a heavy application is similar to a light patch clearcut.

Patch/Strip Clearcuts

With the patch clearcut system small areas (up to 2 ha; 5 ac.) are clearcut throughout a stand, while maintaining the uneven-aged distribution over the whole stand. However, it can be interpreted as breaking up the stand into a number of smaller even-aged ones. The system is intermediate between even- and uneven-aged systems, depending on the size of the patches. If a patch clearcutting system is used within a stand, over time the management system could be considered either even or uneven. The system would be considered to be uneven if the patches are small enough that they would be similar to a group selection system, or if the original stand boundaries were kept, the system could be considered uneven because all of the age classes would be represented within the stand. The system would be considered even-aged if the patches were large or encompassed entire "stands", but then the latter would be clearcutting, not patch clearcutting. Patch clearcutting is often used for natural regeneration of species that are intermediate in shade tolerance.

Very large clearcuts result in erosion, are unsightly, and reduce wildlife habitat. Smaller well planned clearcuts, such as patch and strip clearcuts, can overcome these drawbacks. The groundcover throughout small clearcuts, attracts small rodents which in turn provide food for owls and other birds of prey. Deer and other mammals also feed on this vegetation. Trials in upper New York State have demonstrated how relatively narrow clearcuts (2-4 tree heights wide), that follow land contours, minimize erosion and increase wildlife diversity by effectively creating more forest edge. Furthermore, these clearcuts are zigzagged such that there are visually no long stretches cleared. This vastly improves the aesthetics of the cleared area without affecting harvesting efficiency too much. The abuse of clearcutting in northern Ontario and British Columbia coupled with the media attention it has received, has made clearcutting unacceptable to the public. It is important to recognize that clearcutting in some form is necessary in the management of shade intolerant species such as jack pine, and can create as much habitat as it destroys.

Commercial Harvesting Practices

Commercial cutting practices are those used by loggers without the advice of forestry professionals and are driven only by economic considerations rather than the biology of the forest. These practices are not related to silvicultural systems although they can have that appearance. The main difference regarding the forest is that with commercial practices, there is no concern over the residual stand (except damage to residual trees in some cases), future growth or value of residual trees, species composition or regeneration. Commercial practices should not be considered "forestry practices" as forestry has little to do with the activity or the results. Silvicultural practices tend to be eugenic where there is a tendency to manage for better

quality growing stock. Commercial practices tend to be disgenic, meaning that there tends to be a deterioration in the quality of individuals and the species composition of the forest.

High-grading or "logger's choice" is the most common commercial cutting practice in southern Ontario. In a high-grade, the most valuable trees in the stand are cut. This can be a single species (e.g., red oak) or the best quality trees of many species. High-grading is a disgenic practice which leads to the deterioration in the quality of the trees and the growth of less valuable species. Since merchantable low-quality trees are left in the stand, high-grading can result in a rapid deterioration in stem quality and value in the overstorey. It is often more damaging to the forest as a whole than commercial clearcutting because it can result in total loss of valuable intolerant species from the stand as well as the general deterioration in quality of the growing stock.

One of the problems is that high grading can be quite attractive to a landowner who wants to minimize disturbance and receive the highest immediate return. A logger can offer a great deal of money to cut only a few valuable trees. This is appealing to landowners who need quick cash and do not want the woodlot disturbed too much. If a forester recommends a cut of the same intensity, it will usually include more trees and less money. This is because the forester will tend to remove some of the smaller and lower-quality merchantable trees in order to increase the value of the stand for the future. With forest management the immediate return may be lower, but the return over the long-term will be greater. With time and with considerations made for regeneration of important species there is usually an improvement in the quality.

Commercial clearcuts are the other type of commercial harvesting. Two examples of commercial clearcuts are when all of the conifers are removed from a mixed stand in the boreal forest, and when a stand is cut to the legal diameter limit in a woodlot in southern Ontario. The first example could be confused with high-grading, however it differs as even low-value conifers are usually removed, boreal hardwoods are often unmerchantable depending on the industrial requirements in the area. In a high-grade, only the most valuable conifers would be removed.

In southern Ontario a commercial clearcut is often less damaging to the forest than a high grade as larger openings are created permitting the establishment of intolerant species. Commercial clearcuts in hardwoods will often result in a lot of coppice growth, maintaining the same genetic base as the harvested trees. This may be beneficial if the goal is to regenerate high quality hardwoods.

INSECTS, DISEASE AND CLIMATIC FACTORS AFFECTING CHOICE OF CUTTING METHODS

A variety of insects, diseases and climatic conditions can affect the choice of silvicultural system and cutting methods that are used in a stand. Partial cuttings may be entirely precluded where insect or disease infestations cause problems in the residual stand. Likewise, danger of windthrow is especially severe a) at the edges of clearcuts or in partial cuttings at high elevation, of exposed sites, b) in dense stands or, c) where trees are shallow rooted. In situations where there is a declining stand and residual trees are susceptible to windthrow, clearcutting may be the only feasible alternative. Also, insect and disease infestations are sometimes minimized by partial cuttings rather than clearcutting.

OWNER OBJECTIVES AFFECTING CHOICE OF CUTTING METHOD

Single-tree selection cutting produces the least noticeable disturbance and leaves a stand that looks more like an undisturbed stand than any other cutting method. For this reason, it is often preferred in areas where aesthetics and recreation are priority values, assuming that the species present are suitable. Single-tree selection cutting is often the best for the small woodlot-owner who wants to cut a little timber, but whose main reason for holding the land is something other than timber production. As landowners are easily confused by terminology, foresters will often manage with a shelterwood system and describe it as a selection system to the landowner, simply because it is easier to explain and is often more acceptable to the landowner.

Group selection cutting is usually combined with a single-tree selection cut, creating scattered openings that favour the regeneration of intermediate and intolerant species. In practice, a single tree selection cut often creates openings large enough to suit the purpose of a group selection. In small woodlots, the openings are usually quite small — perhaps one half hectare (1 to 1.5 ac.) or less in size. Group selection with moderate size openings should be appropriate in larger forested areas where the importance of timber and aesthetics are more nearly equal to one another than on high-use scenic areas.

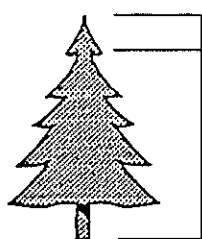
In areas where timber production of intolerant or intermediate species is a major objective, even-aged methods should be considered because of the greater potential volume and value production and reduced administrative costs. Also, intolerant species will often not perpetuate without this type of management system.

WHEN TO HARVEST THE CROP

For timber production, the goal is to optimize production by harvesting the trees at maturity when growth has begun to slow down. Figure 8.2 shows a typical tree or stand growth curve. The current annual increment (CAI) is a measure of how quickly the tree(s) are gaining in height. The mean annual increment (MAI) is a measure of the acceleration of height growth. After the point where these two curves meet, the annual growth rate falls below the average growth increment and the vigour of the tree or stand is declining. The tree(s) may still be gaining in height or diameter, but not at a profitable rate. From an economic perspective, the landowner would be better off harvesting the trees to encourage the growth of younger, more vigorous trees, yielding more return for the dollar. Hence, often the best point to harvest a tree/stand is when the CAI curve meets the MAI curve.

Market prices also play a role in determining when to harvest. If market values are low, the trees may be better stored on the stump until prices improve. Other factors that may influence the owner's decision include the owner's financial situation, concern for environmental conservation and sporting interests.

In a situation where a clearcut is appropriate, the decision to harvest will be based on the health of the stand, economic considerations, or on a growth curve similar to that in Figure 8.2. A decision to do a partial cut of some sort should be based on an estimate of competition in addition to considerations for economics and maturity. Some of the factors which give an index to competition in a stand include the presence or absence of regeneration or forest-floor



Grows .5m this year

10 m tall
at 40 years old

if it grows 5m in the
next 10 yrs

c.a.i. = current annual increment
= .5m

m.a.i. = mean annual increment
= $\frac{10\text{m}}{40\text{ yr.}}$ = .25 m/yr.

p.a.i. = periodic annual increment
= $\frac{15\text{m} - 10\text{m}}{10\text{ yrs}}$ = .5 m/yr

Note that p.a.i. can be used in place of c.a.i. for calculating harvest time.

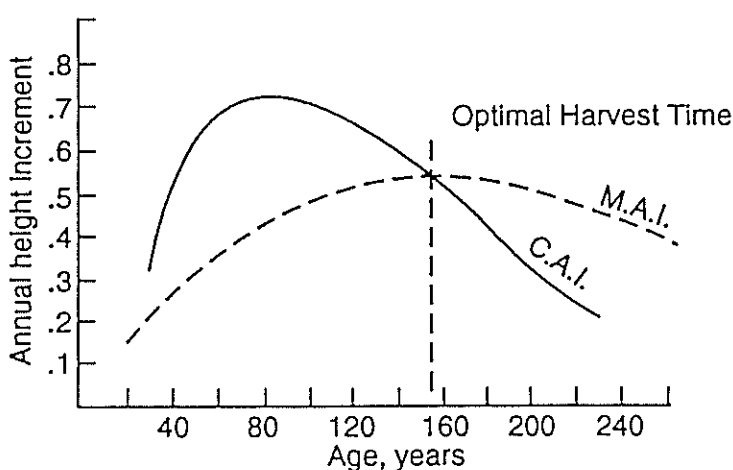


Figure 8.2. Curves for current annual height growth (C.A.I.) and mean annual height growth (M.A.I.)

vegetation, stem form, basal area and the per cent crown closure. Basal area is most often used in practice with some consideration given to stand structure and the other factors mentioned. Basal area is relatively easy to measure and gives a fairly good index of competition since it is related to the total above ground biomass.

For a harvest rather than an improvement cut or thinning, a cut will often be recommended when the basal area is over 20 m²/ha. In most cases, it is recommended that between 25 and 40% of the basal area be removed, depending on stand conditions and silvicultural or ownership objectives. The heavier the cut, the more and larger openings will be created, and the longer it will take before the stand is ready to harvest again. A light cut will alter the stand less and it may support another cut sooner than with a heavier cut. These factors are important to owners, as heavier cuts are more economical, favour different species associations and are less frequent. However, any harvest is stressful to both the owner and the forest.

Review

1. Silviculture involves growing trees to obtain more benefits from forests.
2. Woodlot management must take into account the requirements of the tree species involved, including shade tolerance, regeneration, and succession.
3. An improvement cut is done to improve growing conditions for 'crop trees', not to maximize current income.
4. A silvicultural prescription describes the current condition of a stand and the activity to be carried out. It should include the objectives of the activity; percentage of basal area to be removed during the proposed cut; the likely response of the woodlot to the cut; and the species, sizes, quality and crown position of trees to be marked for harvest. A management system should reflect the silvics of current and desired species, ownership objectives, public use, municipal by-laws, and equipment limitations.
5. The two basic components of a silvicultural prescription are planning (landowner objectives, stand history, silvical characteristics and profitability) and inventory (species composition, mensurational information, stand structure, condition of trees, site conditions, and site potential).
6. Cutting systems suited to even-aged stands include clearcut, seedtree, and shelterwood. Cutting systems suited to uneven-aged stands include single tree selection, group selection, and patch clearcuts. Understanding the characteristics of these systems is necessary to choose the appropriate one for particular management objectives.
7. High-grading, or selective cutting (not to be confused with selection cutting) removes the best trees and promotes degradation of the forest and gene pool.
8. Clearcutting removes all the trees, wide commercial clearcutting removes all the trees of value. The latter leaves poor quality trees which act as seed trees and regenerate the stand with undesirable species and genetically inferior trees.

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Chapter 9

HARVESTING, UTILIZATION AND MARKETING OF WOOD

Timber harvesting is one of the higher profile aspects of forest management and is the first stage in the manufacture or use of wood. Trees are cut for human consumption whether a forester has any input into the decision or not. Prior to 1900, there was virtually no consideration of forest management in the harvesting process. Commercial harvesting practices like high-grading and commercial clearcutting were the order of the day, and remain common in much of the world, including southern Ontario. Not all harvesting is detrimental to a stand. Wood is one of the main products of a forest management program and harvesting is the most common way of manipulating a stand to meet silvicultural objectives. It is essential that tree-cutting practices and harvesting methods be understood so that they can be effectively used to meet ownership objectives.

Owners of small woodlots often cut trees on an annual basis and often have established cutting practices and access routes. They also tend to use small equipment like farm tractors or all-terrain vehicles that usually have light impacts on the forest. However, many woodlot owners do not cut their own wood, and at some point most will want to sell some timber to a logger or other contractor. This chapter discusses the basic processes of cutting trees and the planning, cutting, transportation and marketing of timber.

While income opportunities from woodlands are important to farmers, so is the opportunity to reduce expenses through self sufficiency. Fuelwood, lumber and fence posts are examples of valuable forest products produced and used on many Ontario farms. Markets for a number of forest crops, through direct sale are given in Table 9.1.

Since logs are often best stored on the stump, it is wise to plan what is to happen to a tree before cutting it. Several markets and harvesting options are available, and choosing the most appropriate will depend on available equipment, market conditions, and timing. Planning ahead will reduce the possibility of valuable logs rotting in the bush for lack of sale or means of transport. To maximize both profit from the stand and benefit to the woodlot, woodlot owners must be familiar with the market situation and cut the proper trees at the right time. A forester can assess a woodlot and advise the owner as to what can be sold and its approximate value.

The amount of income and frequency of sales of forest products depends on several variables. Many woodlot owners receive income annually from production and sale of maple syrup and/or fuelwood. However, sales of high quality sawlogs and veneer logs from woodlots are usually made on a periodic basis, generating substantial revenue at the time of sale. Factors affecting the income potential of a woodlot are the location of the woodlot, the species composition, the age and size of

the trees, the merchantable volume of timber, the quality of the timber and the available markets.

It is important that woodlot owners understand how to properly market their forest crops. Choosing the proper trees to cut, selecting the proper method of sale, and selling when markets are good are all important management decisions that must be made to ensure that the woodlot is properly managed and that a good price is received for the products offered for sale.

Table 9-1 Common southern Ontario forest crops.

	Description	Use
Veneer logs	- knot free - high quality - diameter > 12", length > 8'6" - only high value species such as oak, walnut, and ash	veneer
Sawlogs	- most species - diameter > 8" - 12" "	lumber, furniture - use varies with species and grade
Poles	- length 10' - 50' according to product - diameter 5" - 11" - straight with minimal defect	utility poles and construction of log buildings
Posts and pickets	- mostly cedar	fencing
Boltwood	- reasonably straight poor quality sawlogs	pallet industry
Pulpwood	- any species except cedar - decay free - only large volumes saleable	production of pulp and paper
Fuelwood	- high density wood preferred (e.g. ironwood, oak) - defect unimportant- decay free preferred - any wood will burn	for heating
Boughs	- conifer branches	- cedar leaf oil - floral industry
Maple sap	- sweet liquid from maples in the spring	- production of maple syrup, sugar and candy
Christmas trees	- well shaped conifers - often white spruce, or scotch pine	- Christmas trees

* varies with mill

Depending on the products sold, the method of marketing may vary. Timber is usually sold standing (stumpage) for a sum referred to as a stumpage price. Occasionally timber is harvested and sold at the roadside, or delivered to the buyer. Good markets are available for most categories of timber including fuelwood. Fuelwood markets grew rapidly in the 1970s, but have since tapered off

slightly. Such fuelwood markets have provided woodlot owners the opportunity to improve the quality of the growing stock profitably by thinning out poor quality trees for sale as firewood. Split, seasoned hardwood firewood retails for \$170.00 - \$210.00 per bush cord. Fuelwood stumpage prices range from \$15.00 to \$30.00 per cord.

TYPICAL SEQUENCE FOR A TIMBER SALE OR HARVEST

1. DECIDING

When a landowner decides that it is time to consider selling some timber, either because it is specified in a management plan or some other reason, a forestry specialist should be contacted to give some advice to the landowner. Forestry advice on timber sales can be obtained from the O.M.N.R. extensionists or from a private consultant. In any event, the qualifications and background of the forestry specialist and their receptiveness to landowner concerns should be discussed before work is begun. Keep in mind that every landowner and sale is different and any step in this sequence can be left out or modified to suit the landowner.

2. INVENTORY AND PLANNING

The first active step is to inventory the stand and develop a prescription for its management. This prescription could range from no management to intensive management depending on stand conditions and ownership objectives. For an established hardwood woodlot, a prescription will describe the current conditions (inventory), recommend some activities, and describe the expected results of the activities. The activities are usually in the form of a silvicultural prescription that specifies the areas to be cut, and the species, sizes, and number of trees to be from these areas. The results of the activities should be described in terms of wood to be harvested (economics), impacts to the current stand and expected changes in the forest in the future. Operational concerns like access, stream crossings, skidding methods wet areas, and timing constraints should also be discussed in the plan.

3. MARKING

The stand is then marked according to the guidelines in the silvicultural prescription. In a clearcut or patch clearcut, only the boundaries need to be marked; the contract would specify that all trees within that area be cut. In a partial cut, there will be a method of designating which trees are to be cut and which are left. Most often the trees to be cut are marked with tree-marking paint at breast height and again on the stump. They are marked on the stump so that after the trees are cut, it can be verified that only marked trees were removed. By using distinctive marks like a slash or dot, trees can be marked for different products. O.M.N.R. marks trees for sawlogs with a slash at breast height and trees to be sold as firewood with a dot. Prior to sale, an estimate of the volume of wood and number of trees to be cut will be made to estimate the value of the wood for the seller and the buyer.

4. ADVERTISING AND MARKETING

There are two basic methods for selling wood in a timber sale; by a lump sum payment or by the volume harvested (scaled sale). In most cases, especially from a private landowners perspective, a lump sum sale is preferable, but a scaled sale may be appropriate in some situations.

Lump Sum Sale

The timber for sale should be marked and the volume estimated previous to being offered for sale. The timber buyers should then make their own inspections of the woodlot and assess the species, quality and volume of timber. An agreement is negotiated that considers harvesting methods, timing and other areas of concern and the landowner is offered a fixed amount of money to cut the marked trees. It is important in this case for the landowner to receive payment in full, by cash or certified cheque, before any cutting begins. Monitoring during the harvest is important to ensure that trees not included in the sale are not cut.

Scaled Sale

In this case the owner is paid by the volume removed from the woodlot or delivered to a buyer. The sale can be on a gross volume basis, by the cord, cubic meter or board feet. There can also be different amounts paid on the basis of species, grade and volume. Log volume can be estimated by using a log rule or set of volume table. An example of a volume table using the Ontario log-rule is given in the previous chapter. Indirect ways to estimate volume are sometimes used, like payment by weight (pulpwood) or by the piece (fenceposts) but these practices would be considered scaled sales.

A lump sum arrangement is preferable from a landowner perspective because there is a known amount of cash, generally paid in advance. The offer is made on marked, standing trees and the owner knows the revenue at the outset, irrespective of actual yield, quality or operational difficulties. In a scaled sale, the actual cash paid is usually not determined until the wood is cut and hauled away. This can lead to many misunderstandings over the volume, species and value of the timber cut, especially if the landowner or their representative is not on site every day (the owner may not know exactly how much wood is removed). Another advantage of a lump sum sale is the owner requires the logger to cut all marked trees, including some that may be small, poor quality or undesired species, in order to meet silvicultural objectives. In a lump sum sale this should be taken into account, the owner should have enough revenue to pay for cutting these trees if the logger does not.

Advertising

The timber sale should then be advertised to potential log buyers. The O.M.N.R. will include the sale in a regular advertisement that goes out to prospective timber buyers or the landowner can handle the advertisement. The information advertised by O.M.N.R. includes the location, ownership and timber volume by species, number of trees, etc. The advertisement is not binding and the landowner does not have to sell the timber if no suitable contract can be agreed on.

A timber sale can be marketed in several ways. The most common are word of mouth and through mailings that the O.M.N.R. will make to timber buyers. Wood can also be sold by auction, but this is not common in southern Ontario. Some landowners prefer to cut the wood themselves or pay a logger to cut and skid the wood by volume, and then market the products themselves. More often, landowners are not directly involved in the harvesting and marketing of the wood products.

5. NEGOTIATING AND SELLING THE TIMBER

The landowner may then be approached by timber buyers who examine the stand and submit bids to purchase the timber. The landowner should short-list the buyers, check references, then

choose a bid. The landowner should avoid selling unmarked trees to the buyer or logger no matter how small the number. If the landowner is considering the sale of additional trees that should have been marked, then the landowner should contact the forestry specialist who marked the stand (either O.M.N.R. or private) to get their advice. The landowner should insist that payments be in full, in advance, by certified cheque and that all bids be based on estimated volume only. If the logger thinks that the volume estimate is not accurate, they should adjust their bid accordingly.

6. MAKING A CONTRACT

A **written** and signed contract between the landowner and logger outlining the payment and operating conditions is essential to the landowner and is the basis for any good business relationship. Items like timing constraints (e.g., no wet weather skidding), amount of time the buyer is allowed to cut and move the wood (as short as possible), which trees to cut, penalties for cutting or damaging unmarked trees, price, and payment terms should be in the contract. The O.M.N.R. will provide a sample contract along with suggested items to include in the contract, but the O.M.N.R. is not a party to the contract and if they have the resources, can only document violations of the contract specifications.

7. TIMBER HARVEST

Once the timber is sold, the buyer should have the timber cut subject to the conditions outlined in the contract. The landowner should always inform their forestry advisor when cutting begins.

The general process of a harvest is that the trees are felled, limbed, bucked and moved out of the woods to a landing. From a landing, the wood can be loaded onto a truck or otherwise transported to a mill or other user.

8. TIMBER SALE ADMINISTRATION

The progress of the logger should be checked periodically to make sure the contract is being followed. If the contract is not administered effectively, the landowner may have to deal with cutting unmarked trees, or excessive damage to residual trees or the site. It is very difficult for a landowner unfamiliar with the logging business to distinguish between what is necessary for a logger to do and what is convenient. For example, careful falling and skidding can be inconvenient during a harvest, but one cannot be reckless. Also it is sometimes difficult for an untrained person to distinguish between acceptable and unacceptable levels of damage. Another reason to keep tabs on the logging operation is so that the operation can be modified if there are some problems (e.g., in skid trail designation). A timber buyer will often subcontract out the harvesting operations so conditions that may have been understood when the deal was made, may not be understood when the trees are cut; especially if there is not a clear contract.

The contract administration is done by the landowner or their agent (e.g., a consulting forester). If the O.M.N.R. is involved in the sale, they may assist in the monitoring of the progress, but it is legally the landowner's responsibility. The O.M.N.R. can only document problems and cannot enforce the contract, however, the degree of involvement varies with district policy, available personnel and the discretion of the district forestry personnel.

PARTIES AND THEIR RESPONSIBILITIES IN PRIVATE TIMBER SALE

Landowner: Owns the forested tract and provides objectives for management. The landowner selects a bid from a timber buyer which should be based on price and the buyer's past performance. It is the landowner's responsibility to administer the contract.

Timber Buyer: Makes a bid to the landowner to purchase of wood or logs. Timber buyers can represent a mill, themselves (be a logger themselves), or be self-employed as a broker. The timber buyer must purchase logs for the best price possible so that the company can stay in business and be profitable. He/she must consider contract specifications in bid preparation.

Logger: Cuts down trees and sells or takes them to sawmill or other purchaser. They can buy and cut their own timber or be subcontracted by a mill, broker or other logger to cut timber. A logger can be subcontracted to cut all or part of a sale from a timber buyer. A logger or timber buyer is not usually a forester or forest technician and does not normally have any technical background in forest ecology or silviculture. A logger is legally bound to follow the contract specifications during logging operations, whether a subcontractor or not, but have been known to stretch a point. A contract should contain all important considerations and be properly administered to make sure the contract specifications are followed.

Management Forester: Usually has a B.Sc. from an accredited University or equivalent, plus several years experience. Can either be employed by O.M.N.R. or can be employed by the landowner (as a consultant). Occasionally a forester or forest technician, will be hired by a timber company, in which case the landowner must keep in mind that the forester's job depends on the successful and profitable purchase of logs by the mill. The forester can prepare a management plan, silvicultural prescription and/or marking guidelines. He/she can actually do the marking or provide guidelines to a field crew. A consulting forester can provide any level of service that the landowner is willing to pay for. When appropriate, a consulting forester will usually advise a landowner to utilize O.M.N.R. services that may be available at lower costs than through a consultant.

Forest Technician: Generally, carries out tasks specified in a management plan or prescription (i.e., marks the stand according to the silvicultural prescription, usually devised or approved by a forester). Often a forest technician who has worked in woodlot management and harvesting will have more direct experience than a forester and be better at some aspects of sale preparation and administration. A forest technician generally has a 2-year diploma and/or experience.

O.M.N.R.: O.M.N.R. policy is currently in a state of flux and their programs for assistance to private landowners is changing. In recent years they have provided assistance described below. However, these services are changing and may not be available or may be available in different forms in the future. Currently they will provide four days of subsidized forestry advice per year to private landowners without cost. O.M.N.R. foresters will provide management advice according to the landowner's objectives while suggesting secondary objectives (e.g., wildlife management) and incorporating other forest policy objectives (e.g., opposing the subdivision of woodlots). The forest management personnel conducting woodlot

management can be either foresters or forest technicians. This service can include timber marking and providing volume estimates, estimates of market value, advertising the sale to prospective timber buyers, providing a list of timber buyers, and providing a sample contract to the landowner. The O.M.N.R. can document contract violations but cannot enforce the contract; that is the landowners responsibility!

Municipalities: Counties and Regional Municipalities have some influence over harvesting within their boundaries through tree cutting by-laws. The Trees Act authorizes certain municipalities to pass legislation controlling timber harvesting activities within their boundaries. These by-laws generally give a minimum size of trees that can be harvested (a diameter limit). There are exemptions to the by-law such as wood cut for own-use, with good forestry practices. A by-law will vary by municipality, depending on how it is written and approved. Tree cutting activities can also be regulated by cities and towns through the Planning Act.

Violations of tree cutting by-laws are very difficult to successfully prosecute, and the penalties can be inconsequential in some circumstances. The Trees Act is currently under review and it is likely that in the next few years will be revised, changing the types of restrictions that can be implemented and the penalties for non-compliance.

FELLING AND REMOVING THE TREES

Thinning and harvesting is inherently dangerous and it is important for beginners to work with experienced tree cutters until they are comfortable with the hazardous equipment. It is essential to get familiar with safety information and equipment before cutting. Currently, chain saws are most often used to fell trees and cut wood in the bush. Manufacturers instructions regarding use and maintenance of a chainsaw must be followed. Once a tree is cut or felled, it is cut into sections (bucking) and moved from the woodlot (skidding) to where the wood can be loaded onto trucks for transport.

Once the logs have been removed, the farmer may choose to ship them off to a local sawmill or use a portable sawmill to cut lumber for themselves or the neighbours. Portable circular saw sawmills have long been used, but since portable bandsaw mills were introduced in 1982, sales of the former have fallen off. Most woodlot owners prefer the more portable, more efficient and less expensive bandsaw-type sawmill.

TREE FELLING

Careful thought must go into cutting a tree, if it is to be done safely. Trees respond differently based on species, defects, size, lean, terrain, location and many other variables. A cutter must be aware of this, when deciding where and how to make the tree fall. In planning where the tree is to fall, the cutter should consider the lean of the tree, the location of objects in the area (ex. fences, buildings), and the location of the skid trail. Once it is decided where the tree should fall, the operator must plan and clear an escape route in the event the tree does not behave as planned (Fig. 9.1).

Once this is done and everyone else is out of the area, the cutter can begin:

1. The undercut is made to guide the tree in that direction. This is the notch at the base of the tree that removes support for it at that point and increases the tendency of the tree to fall in that direction. The two cuts forming the notch must not cross; the notch must be clean to prevent the tree from splitting. The undercuts shown are based on a 1" opening for every 3" of horizontal cut. Note that there are several variations on this technique (Fig. 9.2).
2. The backcut, or felling cut is made slightly higher than the undercut horizontal, but does not go all the way through to the notch. A hinge is left to guide the tree down and prevent the base from bouncing up.

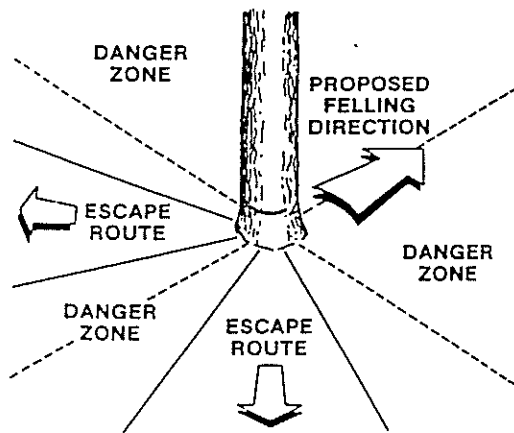


Figure 9.1 Prepare a path of retreat diagonally away from the felling direction

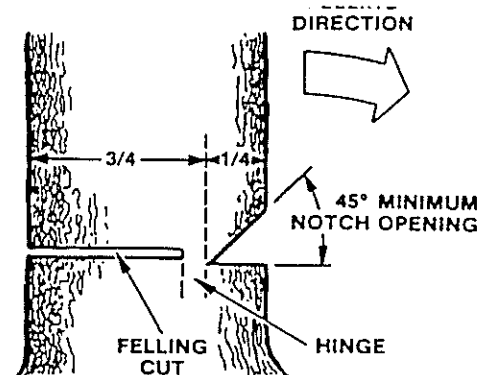


Figure 9.2 Felling a tree with diameter less than the length of the saw bar

LIMBING

Once a tree is cut down, the limbs are removed flush with the stem to simplify handling. In large operations, conifer limbs are removed mechanically. Hardwoods are not suited to mechanical limbing because they generally have larger branches and are not as symmetrical and straight as conifers. In small operations and with all hardwoods, limbs are usually removed with a chainsaw.

Usually the cutter will remove limbs from the base of the tree and work towards the top. Cutting is done away from the body and from the opposite side of the stem, wherever possible. The cutter should be aware of possible tension on branches and take necessary precautions.

The extent of limbing and bucking depend on the particular harvest operation. In an

integrated operation (where more than one product are cut at the same time (e.g., sawlogs and fuelwood), the low grade logs, smaller trees and larger branches are sometimes skidded to the landing with the logs. From here they may be put through a chipper for sale to a pulp mill, cut up as fire wood, or piled and burned.

In some situations, the logs and fuelwood are sold separately. In these cases, the small trees are left standing and the tops left in the bush to be cut for fuelwood later. Conifer limbs left in the bush should be cut so they lie close to the ground. On the ground they will rot more quickly and be less of a fire hazard. Hardwood branches may also be cut to lie close to the ground. This increases the rate of decay and improves the appearance of the woodlot. When cleaning up, the cutter should keep in mind that small piles of brush can serve as shelter for several wildlife species, which may or may not be desirable.

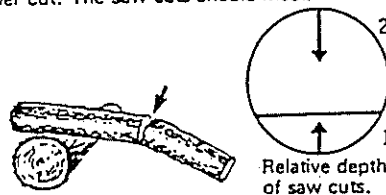
BUCKING

Bucking involves cutting up the tree into sections. Good bucking results in the highest quantity of high quality products, and substantially more money than for poorly bucked logs from a similar tree. Since it is often better to have a good short log than a poor long log, it becomes the buckers job to optimize value by making products most acceptable to the buyer. A buckers must know the relative value of the products, which vary according to mill specifications. These specifications include minimum and/or maximum acceptable diameter, length, number and size of knots, rot, sweep, crook, and other defects. Standard lengths for soft woods are 8', 10', 12', 14', and 16'. Standard hardwood include odd numbered feet. Thus, a 9'11" softwood log would be worth the same as an 8' log, and a 9'11" hardwood log would be worth the same as a 9' log. It is important to measure accurately when bucking to avoid waste. Generally a 3" trim allowance is added to the length of each log to allow for squaring the end of the log at the mill.

Bucking can be done in the bush, at the landing or at the mill. Bucking is one of the more dangerous aspects of tree harvesting. The presence of loose sticks and logs create tripping hazards. Logs may kick, roll, pivot, twist or split when tension is released during bucking. The buckers must be aware of this when deciding where to stand and how to cut the log. Logs supported only at one end tend to split when bucked. This can be avoided by undercutting about 1/3 the diameter and completing cut from the top (Fig 9.3). The top cut should be slightly angled towards the supported end. Logs suspended at both ends will pinch the saw if cut is made straight up or down.

Fig 9.3 A) Bucking a log supported at one end

Firm stance. Begin with a bottom cut. The depth of the cut should be about 1/3 of the log diameter. Finish with an upper cut. The saw cuts should meet.



Bucking tips.

1. Obtain straightest possible logs by making cuts at points of most abrupt crooks. (Fig 9.4)

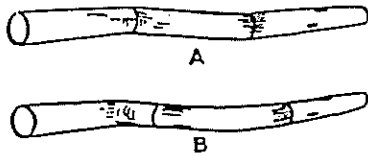


Figure 9.4

2. Measure carefully, Allow correct amount of trim - too much is waste, too little will cause trim to be taken to next shorter standard length Allow extra length as trim allowance, measure from highest point of undercut ,
3. Exclude as many defects as possible and incorporate remaining defects in one log. If the defects are spaced too far apart for this, the tree should be cut with the worst defects arranged to occur at the end of a log. This way they can be trimmed off as part of the trim allowance
4. Make cuts as close to right angle as possible
5. Avoid sawing too close to a crotch, as this will reduce the log grade by creating a double heart at the small end of the log. End log just below fork, take logs independently from fork
6. Minimize the chance of splitting a log. To avoid pinching use a prop under the point of cutting

TREE FELLING EQUIPMENT AND HARVESTERS

Prior to the 1950's, trees were cut using hand operated tools like axes and crosscut saws, dragged (skidded) with horses to a road or river and then hauled by rail or floated down-river to a mill. Since then, chain saws replaced axes and crosscut saws, rubber-tired skidders replaced horses, and large trucks transport most of the logs from the roadside. Although modern chain saws are light and efficient for cutting trees, direct falling of trees with a chain saw is extremely dangerous. Where the trees to be cut are small, labour costs are high, labour is difficult to obtain, or greater safety and efficiency is desired, tree shears or other mechanical harvesters are often used in place of chain saws to cut trees.

MANUAL TREE FELLING

These days, hand tools are seldom used to cut trees in North America. Although hand tools are commonly used in less-developed countries, high labour costs and the easy access to machinery here have made them largely obsolete in North America. Occasionally, an axe or sandvik will be used in precommercial thinnings of saplings or bowsaws used in a thinning of pole-sized conifer stands. Other than that, chain saws are used in the manual felling of trees.

equipment does need to access the area being harvested, requiring a trail and road network, and there are still concerns regarding site quality and protection (soil disturbance and compaction, and regeneration concerns). No matter what the type of cut, the trail and road network will depend on the type of harvest (partial or clearcut), size of trees to be cut, total volume and value of wood to be cut, type and availability of equipment, weather, landscape and site conditions, and the concerns of or constraints imposed by the landowner.

Truck Roads

Under uneven-aged management, a cutting is made in each stand once each cutting cycle (once every 10 to 25 years). Because of the frequent usage, the only feasible approach is to set up permanent truck roads to service all areas. These roads need not be maintained annually, but will have to be opened and repaired for each cyclic cut. This probably means more frequent use than under even-aged management, even where several thinnings might be employed.

There is also a special problem in opening new areas that have not previously been managed, for the cost of the new roads must be borne by the timber removed, and there is no opportunity to harvest a large volume of timber at one time to finance the new road as there is when clearcutting is employed. This is a particular problem in the management of large forested tracts than in the management of an individual woodlot.

The number and location of truck roads depends upon the maximum feasible skidding distance; which depends upon equipment used, topography, etc. With tractor arch equipment, maximum skidding distances are somewhere near 1500 feet, which means that each could serve a strip of forest 3000 feet wide. Thus, a mile of truck road could 350 to 400 acres. The value of timber that can be harvested from this 350 to 400 acres would have to be compared to the cost of building or reopening one mile of roads.

PROTECTION OF THE STAND AND RESIDUAL TREES FROM LOGGING DAMAGE

Logging damage is an especially important consideration in partial cuts as it significantly reduces the income from future harvests because of damage to residual trees, loss of immature trees, and site damage. While impacts of skid trails are pretty obvious, soil compaction off of the trails is hidden from the casual viewer. Soil compaction from skidding operations causes significant site damage, root damage and growth reductions in forests. Soil compaction reduces moisture percolation and aeration. Damage to fine roots from compaction can cause moisture stress on the trees and allow for the entry of pathogens. It is important for skidder operators to stay on designated skid trails and that skid trails be laid out to accommodate their access to the entire stand. Skidder operators should be instructed to winch logs to skid trails rather than drive over to the logs to hook up whenever possible. A permanent skid trails network that can be used again with successive harvests rather than using different trails each time is important to minimize the impacts of vehicle traffic.

Considerable amounts of damage can be done to the residual trees during felling and skidding operations. The most common injuries are breakage of the major limbs or main stems of trees by the felling of adjacent stems, and skinning of bark from the base of residual trees during skidding

operations. Such damage is especially important under uneven-aged methods because of the frequent partial cuttings.

In a study in New York State, logging during partial cutting injured about 30 percent of the residual trees, with major injuries resulting to about 20 percent. Major injuries from felling trees were nearly twice as frequent as those from skidding, although 70 percent of the trees adjacent to skid trails showed some signs of injury. Felling injuries affected about 35 trees and 8 square feet of basal area, while skidding injuries affected about 22 trees and 4 sq. ft. of basal area per acre (Nyland and Gabriel, 1971). There appears to be greater potential to reduce skidding injuries than felling injuries. Most of the serious skidding injuries were concentrated near the major skid roads, suggesting that efforts to control damage be concentrated along the major skidding corridors.

Careful skid trail location and layout are the major ways by which skidding damage can be reduced. Much has been written about proper skid road layout as related to soil and water protection (Nyland 1975, Kochenderffer 1970). The skid roads should be laid out as straight as possible since much of the damage occurs on sharp turns. Where a turn or switch-back is required, attempt to border the margins of the turn with trees that will be removed during the sale. Make all major skid trails as wide as possible to eliminate border tree damage. Be prepared for some damage along these skid roads, and mark a little lighter in these areas so that you can come back and remove the few damaged trees toward the end of the operation without seriously overcutting that portion of the stand.

The choice of skidding equipment (crawler versus rubber-tired skidders, cable-skidders versus grapple skidders) and the skidding of logs versus tree lengths apparently has less effect on the damage to residual trees than commonly supposed. Skidding damage is more frequent along a given length of skid road when rubber-tired skidders are used, but fewer skid roads are required so the total damage balances out.

As previously mentioned, most of the damage to residual trees is done during felling rather than skidding, and unfortunately this type of damage appears less subject to control. Careful supervision of felling with emphasis on directional felling will also help reduce skidding damage as well as damage from the trees falling. Directional felling will minimize broken branches, snapped off trees, and damage from winching or skidding logs to skid trails. If the feller considers skidding requirements, trees will be felled so that they are closer to skid trails and with a straight pull to the skid trail. This minimizes skidder operation off the trails and rubbing against other trees as they are being winched to the skid trail.

Care in marking can also help reduce damage to residual trees. Trees with large crowns that cannot be felled without causing damage to adjacent trees should generally not be marked unless the adjacent trees are also marked. If no space is made, the larger tree may ruin other trees and the landowner may not get paid for them. If it is important to remove the larger tree, it makes sense to mark in the first place if they are likely to be damaged during the operation. Thus, group selection may often be an advantage over single-tree selection cutting for this reason, if groups are at least 1-1/2 times as wide as the height of the larger trees in the stand. The preceding discussion assumes that the markers and tree-cutters can predict where the large tree will fall.

Protection of advanced regeneration of seedlings and of sapling- and pole-sized trees is of

Chain saws are saws, powered by a 2-cycle engine, that are easily operated by an individual. Even a large modern saw will weigh less than 10 kilos (23 lbs). Because of their light weight and rapid cutting ability, they are the main instrument used to cut, limb and buck trees. Because of their power, cutting action, the size and weight of trees and the dynamics of cutting a tree, chain saws are extremely dangerous to operate. A later section describes chain saw operation, tree cutting and safety. With a few exceptions, chain saws are the only tool used to fell trees in southern Ontario. Two exceptions would be brush saws for precommercial thinnings of seedlings or saplings, and mechanical harvesters that are sometimes used in plantation thinnings.

MECHANICAL TREE FELLING

Mechanical tree-felling devices generally attach to a self propelled piece of equipment like a front-end loader or backhoe; or are part of a specially-designed machine. The felling head, or the device that actually severs the tree from the stump, are usually hydraulically powered and cut by pinching or sawing through the tree (Fig. 9.4). Felling heads that cut by pinching work best on smaller trees, those with soft wood and where wood integrity is not important (for chips, pulp or paper). This is because the crushing action of a shear will often shatter or split the butt of larger trees or hardwoods. Felling heads that cut the tree with saw-like cutting heads are used to avoid this problem. Some felling machines will simply cut the tree and let it fall undirected while most will provide at least some direction to the falling tree. In the latter case, the machine grasps the tree a metre or so above the stump while the head cuts the tree; the tree is then pushed in the desired direction. A feller-buncher will gather the cut trees into bunches, placing the bunches off to the side when enough trees are cut. Harvesters, processors or shortwood harvesters will fell, limb and buck the trees into appropriate lengths (e.g., 8 feet). Some harvesters also load the wood onto bunks and forward the wood to the landing.

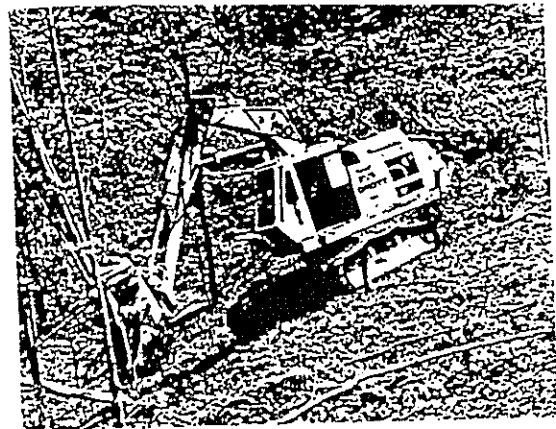


Fig. 9.4 Mechanical harvesters (Courtesy of U.S.D.A.)

TIMBER REMOVAL

FORWARDING

The process of moving wood from where a tree is cut in the bush, out of the bush or to a landing where the wood can be loaded onto a truck is called forwarding. There are two general ways to move wood from the bush; by dragging it (skidding) it, or by carrying it. Illustrations of different types of skidders and forwarders are shown in Figure 9.5. Logs or trees can be skidded many ways; by hand, horse, tractor & chain, tractor & winch, or with a rubber tired skidder. In small operations and with fuelwood cutters, farm tractors are often used. Commercial loggers usually use a cable skidder. Examples of forwarding equipment would be an all-terrain carrier (ATC), a pickup truck, a tractor and wagon, a log-bunk (carrier) mounted onto a skidder chassis or a specially designed machine. Forwarders work the best with smaller logs of regular sizes (e.g., 8 ft.). There are distinct advantages and disadvantages of using either forwarding method and any one piece of equipment.

SKIDDING AND SKIDDERS

During skidding, logs are dragged along the ground out of the bush or to where they can be conveniently transported for use. In the most simple practice, the logs can be dragged by hand, with a horse, or a tractor and chain. Disadvantages of dragging a log on the ground include, greater resistance or drag, ploughing of the soil by the log, and accumulating soil on the log (causing problems with sawing later). The latter problem is minimized by skidding on snow. Advantages of skidding by hand or with a horse are minimal soil disturbance and narrow skid trails. Lifting up the front end of a log with a logging winch while skidding with machinery decreases resistance and some soil disturbance, reduces the amount of soil on logs, and places more weight (and traction) on the drive wheels of a skidding vehicle. Logging winches can be mounted to any vehicle, but are often used with farm tractors or bulldozers that are used in the bush.

A skidder is generally a machine designed specifically for moving logs in the bush and generally used by loggers. The most common skidder is the rubber-tired skidder, a 4-wheel drive, articulated vehicle usually mounted with a blade on the front. A skidder will have a logging winch and tractor arch (cable skidder) or hydraulic grapples (grapple skidder) mounted on the rear to hook onto and skid the logs. Although most skidders have rubber tires, some specialty machines have tracks, and bulldozers mounted with skidding equipment are common in some areas. A crawler tractor (bulldozer) will sometimes be mounted with a winch and used as a skidder. Cable logging systems that draw logs to a landing or road (powered by a stationary engine) are used in steep terrain, mostly out west (very seldom in Ontario).

Farm tractors are quite common in agricultural areas and are the most commonly used piece of equipment for skidding wood in southern Ontario. They are normally used by landowners who manage their own woodlots and small-volume operations which cut fuelwood or thin plantations. The main reasons for their popularity are that they are readily available, relatively inexpensive and can operate in the gentle terrain found in most of southern Ontario. Most people who cut wood



Figure 9.5A Grapple Skidder



Figure 9.5B Cable Skidder

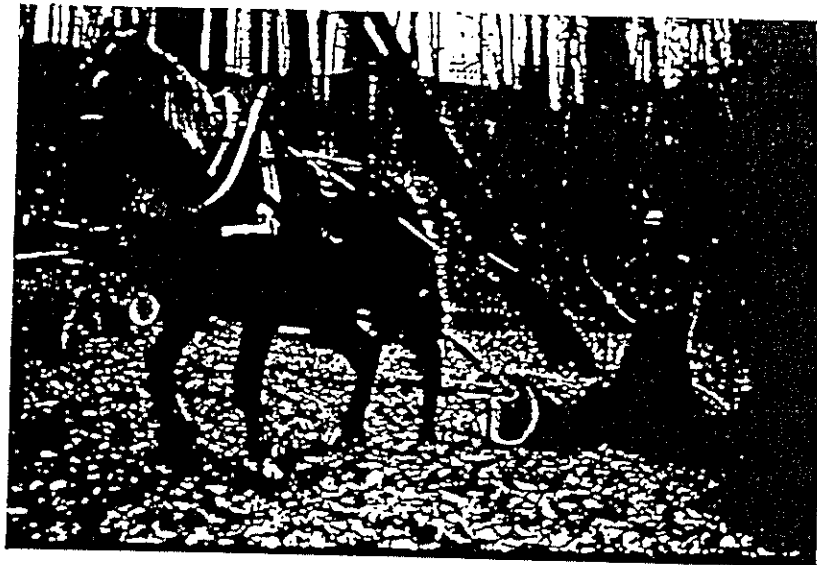


Figure 9.5C Horse Skidder



Figure 9.5D Forwarder

regularly and skid with a farm-tractor will purchase a logging winch that mounts on the tractor and operates off of the power take-off. Since tractors tend to be used by small operators cutting smaller trees in relatively easy terrain, they tend to have light impacts on soil and residual vegetation. It must be kept in mind that farm tractors were not designed for rugged terrain or the weight distribution involved in skidding logs. Disadvantages include safety (high centre of gravity leads to instability and a heavy load can cause the tractor to flip over backwards), a low skidding capacity, limited manoeuvrability (large turning radius), and difficulties with rugged or wet terrain.

LOGGING WINCH OPERATION

Logging winches operate in a similar same fashion as any other winch and their use on a skidder is described below. A log or logs are attached to a main cable by "chokers", winched to the skidder, hoisted off of the ground and skidded to the landing. The main cable is heavier and goes from a drum, over a roller on an elevated tractor arch located on the back of the tractor. The main cable may be 30 metres long, but its length depends on the diameter of the cable (a spool will hold a shorter length of heavier cable), the terrain (longer cables are used in rugged ground or where there is more wetlands), and how old the cable is (cables get shorter with age).

From three to six choker slides are threaded on the main cable and kept from sliding off by a metal "button" pressure-fitted on the end of the main cable. In addition to sliding up and down the main line choker slides hold lengths of thinner cables called chokers. A choker may be two to four metres in length, with a button on each end and a choker slide in between. One end of the choker attaches to the choker slide on the main cable and the other hangs loose to attach to logs. To hook up a log (set a choker), the loose end of the choker is threaded around one or more logs and attached to the choker slide. As the main line is pulled, the "noose" tightens up around the log(s) and they are drawn to the skidder. By using the choker closest to the skidder first, the first set can be winched up, the skidder moved to another location and the cable pulled out to another tree. This process can be repeated until all the chokers are used, the skidder has a full load (weight), or there are no more logs that can be reached conveniently from that spot.

To unhook the logs at the landing or to reset the chokers, the main line goes slack and the button removed (or it falls off by itself) from the slide. The skidder then drives off or the main cable is drawn in to the skidder, it pushes the logs into a pile and goes back for more logs.

The blade on the front of the skidder is fixed (compared to a bulldozer blade) and is mostly used to push logs around (e.g., pile them up on the deck). The blade can also used to do rough levelling in skid trails or skid roads, and to hook over stumps or around trees when winching a heavy load (to keep the skidder from sliding backwards).

When operating a cable skidder, a second person is needed to set chokers in the bush or unhook loads at the landing to make the most efficient use of the machine. Otherwise, the operator must jump on and off the machined to fiddle with the chokers. Often a faller and skidder operator can work together well if the faller sets the chokers. However since most loggers are paid by volume, consideration must be made for the faller taking the time to set the chokers rather than cut logs.

The tractor part of a grapple skidder is the same as a cable skidder, with the exception that cable skidders tend to be a bit larger. The difference is that a set of hydraulic grapples (claws or clamps) are mounted on the skidder instead of a winch and chokers. To skid a log, the skidder is backed up to a log or bunch, the grapple is placed over them and closed. One end of the load is then lifted off the ground and it is skidded to the landing. The operator then drops the logs at the landing, pushes them into a pile and goes back for more logs.

ACCESS ROADS AND TRAILS

Access roads or trails are a necessary part of a harvest operation (Figure 9.6). A skid trail is a path through the bush that a skidder uses to go back and forth between the trees being cut and the landing. Where skidding traffic is heavy, a skid road will be fashioned using a skidder or dozer blade. The landing is where the logs are decked (piled up for short term storage). A hot deck is where the logs are being cut and sorted and a cold deck is where they are being stored. The landing is located on a truck road or timber access road so that trucks and other vehicles can access the logs for transportation. Logs are sorted by quality or by market. They are bucked and otherwise preprocessed, which may include debarking and/or chipping the whole tree or log. Logs or cordwood are usually loaded onto trucks with a log loader (knuckle boom) or a tractor with a fork lift and hauled off to a user.

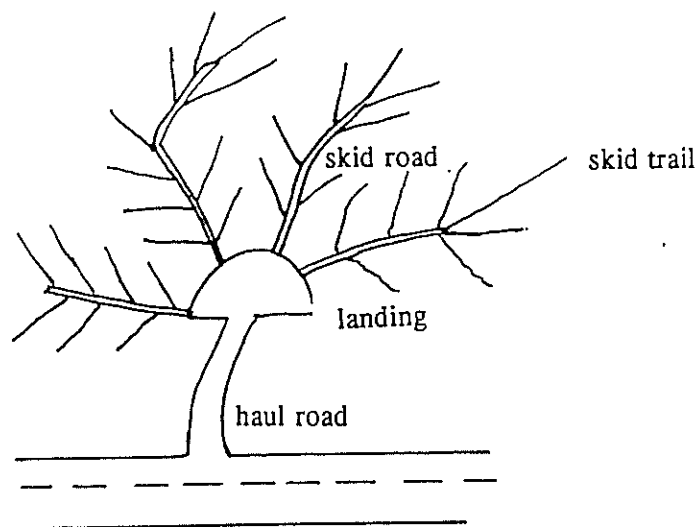


Fig 9.6 Sample access road layout

The problems involved in building roads, choosing proper logging equipment, marketing products and protecting the residual trees, soil and water are not terribly different under uneven-aged management or partial cutting than they are during thinnings under even-aged management. In a clearcut, many of the concerns would be different as there is no residual stand, eliminating the damage aspect and allowing the use of larger and less manoeuvrable equipment. However,

great importance in partial cutting as these trees represent a large part of the future income. Directional felling, careful layout of skid trails to minimize their number, and close supervision during logging are some of the major ways in which advanced seedlings can be protected. However, in some instances the understory may be intentionally disturbed to allow for seedlings of different species to become established.

Some slash treatment or disposal is often necessary needed after most partial cuts. To minimize damage to residual trees, slash disposal should generally be confined to concentrations, should generally be done by hand rather than machine. Lopping the tops to reduce their height and visual impact, and scattering where necessary is preferable to burning. However hand piling and burning may be desirable in small openings. With an integrated sawlog/fuelwood operation, the tops are often salvaged to quite a small diameter making slash disposal a minor or unimportant concern.

FUELWOOD PROCESSING

Industrial use of wood chips or biomass as fuel shares many characteristics with fuelwood production including the use of low quality and smaller material. It is usually conducted on a large scale basis with whole tree, or tree length systems that produce only chips or where the higher quality pieces are sorted out and the rest chipped for paper or fuelwood. Generally, it does not matter what species or quality of wood is used for biomass production. With fuelwood, there are some standards because consumers prefer certain species of wood and do not tolerate rotten wood or insect pests like

As previously mentioned, fuelwood (firewood) is an important forest product because it makes economic use of low grade and small material. To the woodlot owner, this means that trees that need to be thinned or poor-quality trees that will not make sawlog grades can be cut profitably for fuelwood. Silvicultural or stand improvement work that may be a cost to the landowner can often be conducted profitably when the cut trees are sold as firewood. In forested regions (e.g., the Muskokas, North Bay, Parry Sound), firewood is an important product that facilitates the improvement of forests that have been degraded by repeated high-grading in the last 100 years. The poor-quality logs from these stands are often shipped to southern Ontario to fuelwood dealers who process them into firewood and resell it to homeowners. It is usually cheaper to buy loads of logs from up north than it is to buy locally-produced firewood logs (\$80. vs \$100 per bush cord). In southern Ontario, integrated fuelwood/sawlog operations are the norm with grade 3 and lower sawlogs, and often the larger branches, being sold for firewood.

However, too intensive a harvesting for firewood can have negative effects on wildlife habitat when all dead trees, cavity trees and trees of certain species are cut. In areas close to markets, forests can be used too intensively for firewood with the above consequences. Where markets are good near developed areas, retail prices can be quite high (\$200+ per bush cord) wood is used mainly as supplemental heat or recreation. Further from markets, the price drops off and bulk sales (e.g., loads of logs) are often sold to people who burn a lot of wood or who process and re-sell some of it.

Fuelwood is used mainly to heat residences and small businesses. Wood is often preferred as a fuel because of the type of heat it produces (a constant and radiant heat rather than the on-and-

off of a furnace), its cost relative to other fuels (especially in areas with a lot of forest), its romantic appeal, and the pleasure derived from cutting, rendering and burning your own wood. In rural areas, the fuelwood is much cheaper than oil or electric heat, especially if the user cuts all or some of the wood themselves. In more urban areas firewood can be fairly expensive but may still be cheaper than more common fuels. However, many people burn wood for aesthetic or nostalgic reasons in homes or businesses rather than heat value (people have fires because they like them, not necessarily because they heat the house).

FIREWOOD RENDERING

To cut firewood, the logs and branches are bucked (usually with a chain saw) to a lengths suitable to fit into a stove or fireplace (12 to 24 inches in length). The rounds that are greater than four or five inches in diameter are split one or more times until the pieces are small enough to use.

This can be done in the woods, at the landing, at a processing site (loads of logs carried somewhere else to be cut and split). or at the place the wood will be burned. Wood can be sold or transported in a any form or combination imaginable.

In retail markets, firewood is usually sold split and delivered; sometimes green (freshly cut or unseasoned) or dry (~\$190-240). Wood can also be sold retail in rounds (not split), generally for about 1/3 cheaper than split wood (~\$120-140). Consumers who burn several bush cords of wood will often buy a load of logs or pulpwood (~\$80-110) and render it into firewood themselves. Stumpage for standing trees for fuelwood ranges from \$20 to \$40 depending on the location and the wood. The prices in parenthesis are typical urban prices for a bush cord (4' by 4' by 8' or 128 cu. ft) in southern Ontario. It may seem that there is a great deal of money to be made selling wood, but the task demands a lot of equipment and/or a lot of physical labour. Many urban wood buyers do not appreciate the work necessary to produce a cord of wood and how difficult it actually is to make a profit in the firewood business, even at apparently high prices.

People who cut their own wood and small commercial operators will split wood using hand tools, including traditional tools like axes, splitting mauls, and splitting wedges, or with other trendy-modern implements that may or may not work so well. Often people who use lots of wood, sell wood or are have wood that is difficult to split (e.g., elm) will use a hydraulic wood splitter. Hydraulic (or mechanical) wood splitters are can be powered by an external engine (hooked up to a tractor) or by their own engine. Large-volume firewood dealers will use a fuelwood processor to render firewood from logs. Either the logs are taken to the processor (e.g., near a city) or the processor is taken to the logs (at a landing or storage area), the logs are loaded onto the processor which bucks them to the appropriate length, then splits and piles the wood automatically. These machines can be very expensive and require a large volume of wood for them to be profitable.

REVIEW

1. Harvesting is one of the primary techniques used in forest management is not necessarily bad for the forest.
2. Harvesting should be done according to a management plan and be carried out in a manner that minimizes damage to the residual stand.

3. If timber harvesting is to be contracted out, the owner should always get a written contract that includes things like timing constraints, price, volume, which trees to cut, payment terms and penalties for damaged trees.
4. MAR foresters can mark a stand (to meet objectives discussed with the landowner), offer estimates of value and volume, provide a sample contract and advertise the sale to potential buyers at no cost to the landowner.
5. MNR is NOT responsible for ensuring the contract is adhered to; this is the landowner's responsibility.
6. Follow manufacturer's instructions regarding use of a chainsaw.
7. Plan which way is best to fell a tree, and appropriate escape routes before cutting.
8. How a felled tree is bucked can greatly affect the value of the logs. Think before cutting.
9. Forwarders pick up logs and carry them, minimize man hours, are expensive, are intrusive and keep the logs clean. Skidders drag logs, are inexpensive (tractor, ATV, horse, cable skidder), get the logs dirty (affects sawing), minimize compaction and require more time to skid logs.

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Chapter 10

FOREST PROTECTION

Peter Williams and Pauls Jurjans

FOREST EPIDEMICS

Healthy trees will generally be able to resist or outgrow attacks by endemic, or background, levels of diseases or insects. When an individual is put under some sort of stress, it are more susceptible to attack. A good analogy is in humans where we harbour a number of disease-causing bacteria in our throats that normally do not cause a problem. If, for example, a student gets little sleep from studying too hard or socializing too much, they could get a sore throat because the populations of certain resident bacteria get too high. The endemic level of the bacteria doesn't cause a problem, but with increased stress the bacteria multiplies and becomes an epidemic, causing the disease. Once the population of a disease or insect builds up to a certain level, it can attack and overwhelm healthy individuals that would not normally be affected by the disease; the pest has reached epidemic (out of control) levels. With an exotic or other virulent disease, any exposure to the pathogen can lead to the disease and start an epidemic.

The movement of an insect or disease epidemic is fairly consistent. There will often be an advancing "front" of the pest which will advance or retreat at a rate dependent on how the pest reproduces and moves. This front will advance until there is no continuous population of susceptible hosts or it reaches an unsuitable environment. Sometime after the front passes, the population of the pest will decline due to lack of more suitable hosts, or parasites or predators of the pest that build up to where they reduce the pest population. Subsequently, the pest will achieve some sort of balance with the forest. The pest population will often be cyclical or vary from year to year depending on the climate or biological conditions.

Normally hosts and their pests evolve together; the host develops new defences and the pest develops new methods of attack. This coevolution results in a balance. A number of diseases and insects have had disastrous effects on the forests of North America because they have been introduced from other continents where the susceptible North American trees have little resistance to the new pathogen and there were few or no natural enemies of the pest. Local trees do not have the advantage of coevolution.

FACTORS AFFECTING THE LEVEL OF DAMAGE

Several factors influence the scope of damage resulting from the action of forest pests. The vigour or health of a tree has a large influence on its response to insect attack. Was the tree previously defoliated? Is the tree growing in a sub-optimal site? Has drought been a problem? Trees stressed or weakened prior to insect attack are more vulnerable and susceptible to damage.

The time of year that defoliation occurs is important. Early season defoliators, such as gypsy moth, will have a larger impact than late season defoliators, such as fall webworm. Most photosynthetic activity in temperate zones occurs during spring, and consequently, the removal of leaves and needles in late summer or fall will have a minimal impact upon tree growth.

The size of the tree when it is attacked will affect the resulting level of damage. Seedlings and saplings are more vulnerable than mature trees. Root feeding insects may kill seedlings, whereas mature trees are rarely affected. In addition to size, the part of the tree subject to attack is important. Trees may recover from repeated severe defoliations, or the death of some branches, or roots; but, once a tree is girdled, it will usually die. Sometimes a girdled tree survives by coppicing. Some species coppice readily and young trees coppice more easily than old ones. Insects attacking buds, terminal branches, and especially the terminal leader, will have a potentially deleterious effect upon the growth form of a tree. The least important part of the tree with regard to insect attack is the foliage. Generally, defoliators cause minor long-term damage, unless their attack is severe, sustained, or occurs early in the growing season.

When the intensity and duration of attack is increased, trees will suffer correspondingly greater damage. Most serious forest pests have only one generation per year, which means the insect stage responsible for doing damage is only present for only part of the growing season. Other pests, such as aphids, may have several generations per year. If conditions are favourable, they are able to multiply repeatedly, amassing large numbers that attack the host tree on a continual basis throughout the growing season. Trees that suffer heavy and repeated annual defoliations, or are defoliated a second time after having refoliated, will suffer a general decline in health. As health declines, a tree's tolerance or resistance to further attack is decreased.

DAMAGE AND THE RESULTING IMPACT

Three related terms, injury, damage, and impact are often mistakenly used interchangeably. Injury refers to something that is morphologically or physiologically wrong with a tree. Damage refers to the interpretation of that injury. For example, a loss of foliage will be the injury suffered by a tree, while the resulting loss in tree growth (i.e. loss in m^3 of wood/ha) would be the damage. Impact refers to the significance of the damage from the human perspective (one m^3 of oak is worth more than one m^3 of poplar). Impact is usually expressed in monetary terms, to facilitate pest management decisions that need to be based upon the comparison of cost/benefit ratios. The 5 most economically significant insect pests in Ontario are spruce budworm (*Choristoneura fumiferana*), forest tent caterpillar (*Malacosoma disstria*), gypsy moth (*Lymantria dispar*), white pine weevil (*Pissodes strobi*) and sugar maple borer (*Glycobius speciosus*).

In order to assess the impact of forest insects and diseases, one must estimate the monetary value of the trees that are at risk. The value of trees is affected by their location, age, species composition, tree health, etc. For example, a one hectare stand of prime mature oak located close to a lumber mill, has a much greater value in terms of forestry products than a one hectare stand of pulpwood in a remote, northern location. While values for wood products are available, difficulty arises when estimates are required for insect damage to non-material entities, such as aesthetic and recreational concerns. Defoliators may have a negligible affect upon tree health, but the nuisance of numerous, wandering larvae, and the absence of green foliage, may have a dramatic effect upon economies dependent upon tourism and recreation.

The decision whether to spend resources in an attempt to control insect damage should be based upon a cost/benefit ratio. Does the value of the potential benefits outweigh the cost of the control program? In Ontario, a decision to spray for pests in commercially operated forests must meet additional criteria. The wood resource at stake must be economically irreplaceable, and the area must be planned for harvest within 10 years of spraying. By far the most common decision regarding insect outbreaks on crown land is to do nothing, and let the outbreak run its course. Control measures are more frequently undertaken on high value forests, such as plantations and seed orchards. Private landowners have the option to control forest pests as they see fit. The problems and concerns of private landowners are often different than those of the forestry sector.

FOREST ENTOMOLOGY

INTRODUCTION AND IMPORTANCE

Forest entomology may be defined as the study of the effects of insects upon forests, forest products, and the forest environment. Although entomology refers to the study of insects, forest entomology usually includes the study of closely associated life forms, such as mites. Forest entomologists study insects in order to prevent the adverse effects of insects from reaching economical levels. If insect populations have reached damaging levels and control measures are deemed necessary, the forest entomologist must select an appropriate, ecologically accepted control program.

One concern of the forest manager is the reduction of preventable losses to the forest base. Natural depletions of the forest resource are primarily caused by the actions of fire, insects, and disease. Canada's forest fire prevention and control programs are very effective in reducing losses due to fire. While losses of wood resulting from disease agents are very significant, the severe difficulty in controlling disease agents precludes reducing losses from this cause. Each year in Canada, insects on the average damage approximately as much wood fibre as is harvested. However, damage may occur to lesser value species. Biological control programs and modified silvicultural methods have shown promise in reducing insect damage. If forest losses attributable to insects are reduced, there can be a corresponding increase in the annual allowable cut.

Over time trees are subject to insect attack, as are harvested trees, and wood products. In addition to damaging trees, insects may alter the forest environment. For example, when insects kill a significant number of trees in a stand, the resulting increase in sunlight that reaches the forest floor will alter the forest microclimate. Habitats once shaded and moderated in terms of temperature and moisture, are now exposed to direct sunlight, which affects the forest floor plant community, wildlife habitat, and the water table. After an insect attack, dead and dry trees may provide wildlife habitat or pose a forest fire or safety hazard. By affecting the local forest ecosystem, insects can reduce the suitability of forested areas for recreational and tourist use.

In Ontario most forest entomology research is conducted by the Forest Pest Management Institute in Sault St. Marie, Forestry Canada at the Forestry Canada, Ontario Region Forestry Centre, and O.M.N.R. at the Universities at Guelph, Lakehead, and Toronto. The operational side of forest protection (protection from insects, fire, and disease), is the responsibility of the Ontario Ministry of Natural Resources.

INSECTS AND TREES

It is important to remember that insect and trees have co-evolved. While trees initially appear defenceless towards insect attack, they have evolved defence mechanisms. Insects that bore into trees, are usually drowned by tree sap, or "pitched out" by tree resins. Broadleaved trees have an excess number of leaves (photosynthetic organs), so that even up to 50% of the leaves may be removed without observable effects on tree growth or general tree health. From a tree's perspective, one half of its leaves are expendable. When defoliation exceeds 50%, broadleaved trees begin to suffer reduced growth. If the tree is severely defoliated early in the year, the tree will refoliate itself during the summer. Although the tree has utilized some of its stored energy reserves to refoliate, photosynthesis from the new crop of leaves will help to compensate for the loss of the initial crop of leaves. Studies have shown that if trees have experienced stressful defoliations, a change occurs in the chemical composition of leaves in following years. The chemical changes, such as increased tannin levels, help to reduce the vigour and fecundity of defoliating insects.

Most species of insects play important beneficial roles in the forest ecosystem. Insects act as primary pollinators for many species of flowering plants and crops. By decomposing and scavenging dead plant and animal material, insects help to recycle essential nutrients, and enrich the forest soil. Insects also act as an important food source for many fish and wildlife species.

INSECTS AND THEIR SUCCESS

Insects comprise an extremely important, numerous, and diverse class of organisms. Approximately 75% of all described animal species are insects, with several million species of insects yet to be described. While about 50% of insect species consume plant material, less than 1% of species compete with man for food or fibre.

Insects are remarkably successful in terms of their diversity and ubiquity. Part of their successful nature stems from their tremendous reproductive potential, quick generation time and high genetic variability. High reproductive potential allows for sudden large increases in the density of insects (i.e. outbreaks), while their genetic variability allows for them to evolve quickly. Although the development of insect resistance to chemical insecticides has not been a problem in forestry, several major agricultural pests have become resistant to many commonly used insecticides. Because of their relatively small size, insects are also able to resourcefully exploit countless niches. Most insects are winged for at least part of their life cycle, so they are able to actively disperse into new areas.

Fortunately, the density of most insect species is kept within innocuous levels through a combination of several biotic and abiotic factors, collectively known as the environmental resistance. These factors include among others, competition (both within and among species), parasites, predators, pathogens, food resources, weather conditions, and tree vigour. Due to their high reproductive potential, a small shift in the intensity of one or more of the environmental resistance factors may allow insect populations to increase and reach damaging levels. While the density of some insect species reach pest status sporadically, other pests tend to follow a more regular, cyclical pattern.

TYPES OF INSECT DAMAGE

Insects damage trees in several ways. The most common form of tree damage is reduced growth. As mentioned above insects that consume leaves, or remove plant sap may create a sublethal stress that retards tree growth. While most trees recover from this, a recurring loss in growth over large areas may have serious forest management implications by increasing the rotation age.

Insects may also responsible for causing tree mortality. While a tree is generally quite resilient to insect attack, the cambium is quite vulnerable. The cambial layer of the main stem can be regarded as the tree's lifeline. If insects attacking the cambial layer encircle the trunk, the tree will be effectively girdled and dies. Trees may recover from repeated severe defoliations, or the death of some branches, roots etc., but once the tree is girdled, it will succumb relatively quickly. Insects that normally cause a loss in tree growth may kill trees if the attack is repeated for several successive years. Broadleaved trees commonly recover from successive severe defoliations lasting three to five years, but if the defoliations, or other stresses continue, the tree will eventually succumb. Evergreen tree species retain their needles from three to seven years. Older needles store starch as well as photosynthesize. Consequently defoliation is serious for evergreens than broadleaved trees. Evergreens often die after one complete defoliation, although trees that suffer moderate to severe defoliations usually recover.

Insects that cause a sublethal stress may contribute to tree mortality when their actions occur in conjunction with other stresses. For example, if a tree has suffered from heavy defoliations, drought, and lack of nutrients, the resultant net stress may overwhelm the tree, even though the tree could withstand the individual stresses. Insects may also kill a tree indirectly by vectoring, or allowing the introduction, of pathogenic organisms such as fungi. For example, boring insects

may allow the introduction of wind disseminated fungal spores by creating a break in the tree's outer defence mechanism (i.e. the bark). The native and European elm bark beetles vectors *Ceratocystis ulmi* to new elm hosts (Dutch elm disease). Pathogens may cause a devaluation of wood resources through reduced growth, death, or wood staining.

Insects may also damage forest resources by disfiguring trees. By attacking the terminal leader of pine saplings, insects such as the white pine weevil, may cause forking or turning of the main stem, thereby devaluing the tree's potential for lumber purposes. Trees that are valued for their appearance, such as Christmas trees, will be devalued if the foliage or branches are damaged. While the disfigurement of trees is less important with regards to pulp and paper usage, disfigured trees may add to harvesting costs.

CLASSIFICATION OF FOREST INSECTS

Forest insects may be classified in several ways. One of the most functional methods of classification is by the feeding injury that insects cause. Almost all injury to trees directly attributable to insects results from their feeding habits. Insects obtain their food from plants by two strategies. One group of insects has evolved mouthparts that are adapted for piercing plant tissue and sucking plant fluids. Another other group has evolved chewing mouthparts, which are able to chew and ingest plant material.

Insects with piercing/sucking mouthparts attack either foliage or stems. Symptoms of this type of injury include wilted, off-colour foliage, flagging (death of branch tips), or deposition of honeydew (exudate that insects excrete in order to concentrate plant sap). When enough sucking insects feed on one plant, they cause a general decline in tree vigour, which may lead to the death of branches, or in extreme cases, to the death of the tree itself. Most forest trees will tolerate significant numbers of these pests without any major effect. Most sucking insects belong to the insect order Homoptera, and include aphids, scales, and spittlebugs.

Insects with chewing mouthparts have specialized their feeding habits such that no part of the tree is immune from attack. Insects that consume foliage are known as defoliators. This group comprises the most important pests affecting forest trees in Ontario. Most defoliators belong to the order Lepidoptera (includes moths), while others belong to the order Hymenoptera (includes sawflies), Coleoptera (beetles), and Diptera (true flies). Partially eaten foliage is the most common symptom. Some defoliators roll leaves up, or fasten needles together, with a web of insect silk. Defoliators can be further classified as

1. whole leaf defoliators, which consume entire parts of leaves or needles;
2. miners, which feed upon the internal contents of leaves or needles; or
3. skeletonizers, which consume the leaf material between the leaf veins and leave the veins intact.

Insects that feed on the phloem and adjacent surface of the wood comprise the second most important group of insects attacking trees in Ontario. Any part of the stem or branches may be affected. The most important pests in this group include three genera of bark beetles, *Dendroctonus*, *Scolytus*, and *Ips*. These pests usually attack trees previously weakened by some other cause, such as drought or damage from harvesting operations. Attacks are concentrated on individual trees by the use of aggregation pheromones (chemicals released by the pest that attract other members of the same species). Only by attacking in large numbers will the beetles be able to overwhelm the tree's defence mechanisms, and avoid being drowned in plant sap or being "pitched out". Many of these pests transfer fungal pathogens that often invade the sapwood and reduce the transport of water to the tree crown. Symptoms include the death of individual branches or sections of a tree, and the presence of feeding galleries which look like lines etched on the inner bark.

Borers are insects that may spend some time feeding on the inner bark, but often complete part of their life cycle by feeding on the sapwood and the heartwood. Many pests in this group belong to two families of beetles, *Cerambycidae* (the longhorned beetles), and *Buprestidae* (the metallic wood borers). They will attack any part of the stem or branches. Symptoms include the presence of feeding tunnels in the inner bark, or throughout the inner wood. Damage by these insects, before and after felling, reduce lumber value.

Insects that cause injury to growing tips are known as terminal feeders. Many taxonomic groups are involved, including twig beetles, terminal weevils, aphids, scale insects, spittlebugs, and twig-boring caterpillars. Damage is most serious when young seedlings and saplings are attacked. Symptoms include flagging, droopy terminals, or disfigured terminals (forked or crooked). These pests reduce timber potential and damage the appearance of ornamentals by disfiguring the tree.

The feeding of some insects and mites stimulates the tree to produce an abnormal growth called a gall, which serves to surround and protect the feeding insect. Damage resulting from gall makers is negligible in the forest environment. Although tree health is not threatened, the presence of unsightly galls on shade and ornamental trees may be cause for concern.

The small and fibrous roots of trees may be damaged by insects such as wireworms, whitegrubs, and certain weevils. The most serious damage occurs in tree nurseries. Trees in a forest environment are seldom affected.

Some insects have specialized as seed and cone feeders. In a forest environment, control measures are not required, due to the large number of seeds produced. Damage may be of concern when genetically superior trees in seed orchards, or seeds in storage, are attacked. Insects in this category include several *Lepidopteran* and *Dipteran* species.

INSECT DETECTION AND SURVEYS

The status of serious forest pests is monitored on an ongoing basis by the Forest Insect and Disease Survey unit (FIDS) of Canadian Forest Service. Using a combination of sources,

including remote sensing (aerial observation), public and private observational input, and insect rangers on patrol, FIDS determines the extent of insect outbreaks (area affected), and the pest species involved. This information is then utilized by and the O.M.N.R. in planning control strategies.

Two basic sampling strategies are widely utilized in insect survey work. Pheromone traps are effective in detecting the presence or absence of pest species, especially exotic (introduced) species, such as the gypsy moth. Other sampling methods are employed to evaluate the density of insects. These include counting the number of larvae per branch, the number of egg masses per hectare, or the number of aphids per leaf.

METHODS OF INSECT CONTROL

A forest pest control program should be based upon a sequential process. The initial fundamental step is to inspect the forest resource on a continual basis, and attempt to detect any tree abnormalities or problems at as early a date as possible. If trees are experiencing some type of problem, the causal agent(s) need to be identified. Once proper identification is made, the significance of the problem must be evaluated. If deemed necessary, artificial control options are considered and assessed. Control strategies are then planned and later undertaken. An important final step is to assess the effectiveness of the control program and the problems that were encountered, so that future control strategies may be refined.

Six basic control strategies are available for the control of forest insects.

Summary of insect control strategies.

1. Mechanical / physical
2. Legal / quarantine
3. Cultural / silvicultural
4. Biological
5. Chemical
6. Genetic
7. Integrated Pest Management (IPM) - a combination of the six methods above.

To prevent the introduction or dispersal of new pests, the government may quarantine shipments of goods, such as nursery stock or lumber products. Such materials then require a phyto-certification permit before they can be imported into, or exported out of, Canada. While this method makes international or interprovincial trade more cumbersome, it may prevent or delay the introduction or spread of serious forest pests.

Physical exclusion of insects is impractical on a large scale, although some adaptations may be possible. For example, trees that have been felled but remain in the forest are subject to attack by boring insects. If the logs are immersed in a mill pond until they can be used, damage from borers will be minimized. On a small scale, insects may be excluded to a large degree from areas such as seed storage facilities, and greenhouse nurseries.

Cultural/silvicultural control refers to control options that can be utilized by modifying normal forest tending and harvesting practices. For example, the white pine weevil is a serious pest of terminal leaders in young white pine plantations. If white pine are planted in the shade of a nurse crop of trees, the problems associated with this pest will be alleviated. Pure stands (monocultures) offer the opportunity for some insects to multiply into populations large enough to overwhelm healthy trees in a stand that would not otherwise be affected. Diverse stands do not offer these insects a chance to reach such high populations. If a particular pest presents serious problems in pure stands, perhaps diversifying future stands may help to reduce outbreaks of the pest.

Introduction or augmentation of a pest's natural enemies (parasites, predators, and pathogens) to help control pest populations is known as biological control. Biological control agents can either be self-perpetuating, or reared in large numbers and released at an appropriate time to inundate the pest population. While the theory of biological control is potentially very cost effective and environmentally sound, few biological control successes have been recorded for forest pests. Introduced pests are thought to be prime candidates for biological control, because many or all of the natural enemies associated with the pest in its native range, are usually absent in the introduced site.

Chemical control refers to the application of chemical insecticides to reduce insect damage to a tolerable level. Insecticides are most effective when insects are exposed and actively feeding, such as whole leaf defoliators. Application on a small scale basis may be made from the ground, while applications on large or inaccessible areas are made aerially by rotary or fixed wing aircraft. Few chemical insecticides are registered for use on forest pests in Canada. Two insecticides, carbaryl (Sevin_R, a carbamate) and fenitrothion (Sumithion_R, an organophosphate) are still in use. Most chemical insecticides work by contact action, so that the insect must come in contact with the chemical. Contact insecticides are ineffective towards insects that are protected from contacting the chemical, such as bark beetles and leaf mining insects.

Various factors determine the effectiveness of insecticide applications. The size of spray droplets and their distribution throughout the tree crown are important parameters. The development of the insect in the field must be monitored so that applications are synchronized with the developmental stage of the insect that is most susceptible. The resistance of insects to chemicals is of great concern in agricultural systems; fortunately, the development of insect resistance has not yet been detected for any forest pest.

While the effectiveness and cost of chemical insecticides are positive attributes, several negative factors should be considered. Most chemicals are non-selective, killing beneficial insects as well as pests, while others are also toxic to fish and wildlife. Effects of their long term use remain largely unknown. Residues of the chemical or its breakdown products may contaminate water sources. Although all insecticides registered for use in Canada have passed a rigorous screening program, surveys have shown that the Canadian public has a negative reaction to the use of chemical insecticides for forest protection purposes.

Biological insecticides are a relatively new class of insecticides that have shown greater public acceptability than their chemical counterparts. In these insecticides, the active ingredient is a

biological agent, such as bacteria or a virus. One bacterial insecticide, *Bacillus thuringiensis* (*B.t.*), has seen widespread use against Lepidopteran pests (moths). Since 1985, all forest spray programs conducted by the O.M.N.R. have used *B.t.* The major advantages of *B.t.* are its selectivity (minimal effect to non-targets) and its public acceptance. The effectiveness of *B.t.* varies from fair to excellent in most forest application situations. When the density of pests is very high, *B.t.* is considered less effective than chemicals. The selectivity of *B.t.* however, (effective only on Lepidopteran pests), precludes its use against several other important forest pests. Biological insecticides need to be ingested in sufficient quantities before they are effective. Applications need to be timed so the spray can be adequately deposited on foliage. While *B.t.* can be reared on media, viruses need to be produced by rearing and infecting host insects. Viruses can be very effective and are usually host specific, but current production costs prohibit large scale use. *B.t.* and three viral insecticides are currently registered for forestry use in Canada.

Insect growth regulators (IGR's) are a new class of insecticides. This group consists of insect hormone analogues that are used to disrupt normal insect development. Insects are prevented from reaching the adult stage by interfering with development. IGR's are more specific than chemical insecticides, but are not species specific, so their application may harm beneficial insects within the same genera as the target species.

Genetic control refers to the manipulation of the genetic makeup of the host tree, the pest, or the pest's natural enemy. While current efforts using genetic control have shown little success, the constant improvements in genetic technology may facilitate future success. It may become possible to make trees more resistant to insect attack, natural enemies more effective, or insect pests less successful.

Integrated pest management (IPM) attempts to manage pests by using a combination of suitable control methods. The level of a pest population is kept tolerable through the use of preventative, and if required, corrective control measures. Insecticides are used only when necessary, and their use is planned to minimize their adverse effects upon non-target species.

For maximum effectiveness, IPM must be integrated with forest or plantation management. Harvesting and silvicultural practices may need to be modified to facilitate the management of insect pests. For example, if a pest is known to become a problem once forests become mature or overmature, efforts should be made to harvest susceptible stands before the pest population reaches damaging levels.

INSECT ECOLOGY

For effective pest management, the understanding of the ecological factors affecting a pest population is of paramount importance. The more that is known about a pest, including its dispersing ability, preferred hosts, mortality factors, habitat, preferred climatic conditions, and predators, the better one can forecast future population trends and implement a suitable IPM program. Understanding an insect's life cycle is a fundamental step towards knowing its ecology.

Because of their rigid exoskeleton (outer covering), all insects must go through a moulting process. When immature insects grow to a certain size, they must shed their old exoskeleton (i.e. moult). The new exoskeleton accommodates a larger insect, until it too must be shed. Moulting continues until the adult stage is reached, at which time it ceases. The stages between moults are known as instars.

The basic life cycle of the most serious tree pests (moths, sawflies, and beetles), is called complete metamorphosis. In this process, the immature stages, known as larvae, and the adult insects, are usually quite different in terms of their appearance, habitat, and habits. The cycle begins with the egg, from which the first instar emerges. Larvae are wormlike, with the different larval instars being similar in their appearance, except for an increase in size with each successive moult. Larvae have chewing mouthparts and are usually responsible for all or most of the damage caused by the pest. After the last larval instar (usually there are from four to six instars), the insect moults into the pupal stage. This stage is inactive (no feeding), and allows for the metamorphosis from the wormlike larval stage to the winged adult stage. The pupa is often surrounded by a hard outer covering known as the cocoon. Once metamorphosis is complete, the pupa moults to the adult stage. Reproduction, both in terms of mating and oviposition, occurs during the adult stage. The adult stage is also usually the dispersal stage.

The life cycle modifications that insects have evolved show great diversity. Insects overwinter in the egg, larval, pupal, or adult stage according to species. Some species have one generation per year, others have several. Some species can reproduce parthenogenetically (without fertilization) if males are sparse, while for some other species, males appear to be nonexistent. While natural enemies of an insect pest may attack any developmental stage, insecticide applications are only effective against active stages (i.e. larval or adult stage). Although development may still be occurring internally, the low activity of eggs, pupae, and the senescent overwintering stage, render insecticides ineffective during these times.

FIVE FOREST INSECT PESTS IN ONTARIO

SPRUCE BUDWORM (*Choristoneura fumiferana*)

The spruce budworm (SBW) is the most destructive forest pest in Canada. It is found throughout eastern Canada, and west as far as the Mackenzie river valley. Its preferred host is balsam fir, although white and black spruce are attacked, especially when growing in conjunction with balsam fir. All damage is associated with feeding habits of the larval stage.

The SBW is a native pest that has one generation per year. In July, eggs are laid upon host foliage in masses consisting of 20-50 eggs, with females typically depositing 200 eggs in total. Eggs hatch in about 10 days. After 1 or 2 days, the first instar larvae spin protective overwintering site under loose bark, in old flower scars, or other areas upon the tree. Larvae then moult to the second instar and overwinter. In late May, the second instars emerge, feeding

upon either new buds of staminate flowers, or mining old needles. Once the new shoots begin to expand, larvae begin to feed upon them. When larvae are half grown, they tie two or three adjacent shoots together with silk to form a small nest. Larvae prefer new foliage, but in severe outbreaks, larvae may eat older foliage. Once feeding is completed in late June or early July, larvae pupate upon the host. Adults appear in about 10 days. The female may disperse, but only after she has deposited one or two egg masses. Dispersing adults may be blown for considerable distances by the wind. First and second instar larvae may also be dispersed for short distances by the wind.

Outbreaks of SBW occur over large areas in Ontario (Table 10.1). In 1991, over 9×10^6 ha of forests suffered moderate-to-severe defoliation. After three to five years of heavy defoliation, balsam fir begin to die. In 1991, 3.7×10^6 ha of budworm associated tree mortality, comprised mostly of balsam fir, was found in Ontario. Periodic outbreaks of SBW in eastern Canada have been recorded since the 1700s, which suggests they are a natural occurrence in a balsam fir-spruce ecosystem. While losses of balsam fir in Ontario are large, balsam fir comprises only 8% of Ontario's softwood volume, and only 5% of the annual softwood harvest. Consequently, the impact of SBW on Ontario's forest base is considerably less than in New Brunswick, where balsam fir is heavily utilized by the pulp and paper industry.

Spruce budworm damage may be effectively controlled by the application of chemical insecticides or *B.t.* The vast areas of infested forest, coupled with the low utilization of balsam fir in Ontario, result in only relatively small areas (usually high value) being treated. Although the SBW has been intensively studied, past biological control attempts have met with little success. Ciba-Geigy inc. and various university faculties are currently conducting research on the feasibility and effectiveness of inundative releases of *Trichogramma minutum*, an egg parasite of SBW and other insect pests.

Recommendations have been made for the modification of silvicultural and harvesting practices to help reduce SBW damage. Reducing the balsam fir component in stands, by selected harvesting and/or replanting, will help to decrease the stand's susceptibility to future outbreaks. Favourable overwintering sites on mature balsam fir have been implicated as a significant factor in fostering outbreaks. Consequently, old mature stands of balsam fir should be harvested first. In addition, forests should be managed to produce mixed-aged stands, which are more resistant, rather than even aged-stands, which are more susceptible to SBW attack. If SBW has killed trees, a salvage cut would help to reduce the loss of wood fibre. Managing the forest to make it less susceptible to budworm attack, is the only preventative control technique that is currently available.

A closely related species, the jackpine budworm, is a serious pest of jack pine in Ontario. Its habits and life cycle are almost identical to the spruce budworm, except for that its preferred host is jackpine. White, red, and Scotch pines may also be attacked by jackpine budworm. Fortunately, outbreaks seem to be of shorter duration than those of the spruce budworm. In 1991, approximately 130,000 ha of Ontario forests were moderate-to-severely defoliated by the jackpine budworm.

Table 10.1. Gross area of moderate-to-severe defoliation in Ontario resulting from spruce budworm, forest tent caterpillar, and gypsy moth (1986-1991).

Year	Moderate-to-severe defoliation (ha)		
	Spruce budworm	Forest tent caterpillar	Gypsy moth
1986	8,856,000	433,000	167,776
1987	7,189,763	1,649,977	12,678
1988	5,224,734	3,695,229	29,693
1989	6,239,636	7,915,111	81,640
1990	6,780,446	9,480,408	77,648
1991	9,065,781	18,870,518	347,415

FOREST TENT CATERPILLAR (*Malacosoma disstria*)

The forest tent caterpillar (FTC) is a serious forest defoliator that occurs throughout most of Canada. Its preferred hosts in eastern Canada are trembling aspen, sugar maple, oak, ash, and birch, although many shade and fruit trees can be attacked. Damage from this native insect results from the larval feeding stage.

The FTC has one generation per year. In July, eggs are laid in clusters of 100-350 eggs, with the cluster encircling a host tree twig. The eggs are cemented together and covered with a glue-like coating. FTC overwinter as a complete embryo within the egg, with eggs hatching as the host tree buds begin to swell in the spring. Larvae hatching from an egg cluster are initially gregarious, becoming more solitary as they mature. Larvae leave trails of silk upon the tree, which they follow. They also spin a silken mat on either the tree trunk or branches, upon which the larvae congregate to rest or pupate. Unlike the eastern tent caterpillar, the FTC larva does not spin a protective tent. Older larvae wander over trees and vegetation, searching for new foliage, or places to pupate. Pupation occurs either on host trees or shrubs, with adults appearing in late June or July.

Outbreaks of the FTC in eastern Canada usually last from two to six years, and tend to follow a cyclical pattern. Several abiotic and biotic factors, including virus, low winter or spring temperatures, and starvation of older larvae (i.e. intraspecific competition) may be responsible for population declines. The most recent outbreak in Ontario increased from 433,000 ha in 1986 to over 18 million ha in 1991 (Table 10.1).

Heavy defoliations result in loss of tree growth, and some branch killing. Over a three year period (two years of defoliation and one of recovery), poplar trees affected showed a 58% average drop in growth rate. Estimates of annual damage to sugar maple in Ontario, included tree mortality losses of approximately 600,000 m³. Some of this mortality likely resulted from the contribution of FTC to the maple decline stress complex. Heavy defoliation and the large numbers of wandering larvae, can have a significant effect upon areas dependent upon recreation and tourism.

While outbreaks of FTC can be extremely large, they typically subside after three to four years. Control options are consequently rarely undertaken by the O.M.N.R.. If required, *B.t.*, or chemical insecticides can be applied once the young larvae become active in the spring. On a small scale, egg clusters from small trees can be collected and destroyed during the winter months.

GYPSY MOTH (*Lymantria dispar*)

The gypsy moth was initially introduced into North America near Boston in 1869. It has since spread throughout northeastern U.S.A. and into southern Ontario and southern Quebec. Gypsy moth is a serious defoliator of many deciduous and occasionally coniferous species. Preferred hosts include oaks, birch, and poplar, but its diet includes over 400 North American plant species. While young larvae cannot complete development on conifers, older larvae do well on these species.

The gypsy moth has one generation per year. In July, eggs are deposited in egg masses that average 400 eggs, although some egg masses may contain more than 1,000 eggs. Egg masses are commonly found on tree trunks, the underside of branches, on shrubs, or on ground debris. Eggs develop into a complete embryo, and then overwinter. The following May, eggs hatch as the oak buds start to flush, and the larvae move upwards to find foliage. First instars can be easily dispersed by the wind. The first three larval instars remain on the foliage day and night, while later instars feed at night, and seek daytime shelter under bark, or in the leaf litter. In high density populations, larvae remain on the foliage day and night. When feeding is completed, larvae pupate, either on the host or in the leaf litter. Adults emerge after 10-14 days. Female adults, although winged, are unable to fly, and thus do not disperse.

The gypsy moth was initially detected in Ontario in 1969. It remained largely inconspicuous until the early 1980s, at which time the area suffering moderate-to-severe defoliation started to increase. The initial outbreak increased until 1985, at which time about 250,000 ha in southeastern Ontario were defoliated. Since 1985, the outbreak decreased to 13,000 ha in 1987, and then increased until 1991, when 347,000 were defoliated (Table 10.1). The initial infestation that was concentrated in southeastern Ontario has now largely collapsed, and numerous smaller infestations have developed throughout southern Ontario. Forest stands with a high component of oak appear to be most susceptible to gypsy moth attack, as are upland sites, particularly those with scrubby oak.

Damage resulting from gypsy moth attack is varied. Gypsy moth, like spruce budworm and forest tent caterpillar, is an early season defoliator. Consequently, severe defoliations will have maximal effect upon reduced growth rates. During severe outbreaks, gypsy moth will strip the leaves off almost every tree. Conifers growing in conjunction with preferred hosts may be likewise stripped of all foliage, possibly resulting in their mortality. The present range of gypsy moth in Ontario coincides with some of the more heavily populated areas of the province, as well as some of the prime cottage and recreational areas. During heavy infestations of gypsy moth, the public's use of cottage and recreational areas is reduced, resulting in losses to local economies. In Ontario, gypsy moth is seen more as a people problem, rather than a forestry problem.

Because of its introduced status, gypsy moth would seem to be an ideal candidate for biological control. The United States has expended large efforts in foreign exploration, and has introduced several parasites and some predators. Approximately 10 species have become established, and are believed to impart some measure of control, although large outbreaks still occur. Dense populations of gypsy moth are decimated by a naturally occurring viral disease (nuclear polyhedrosis virus), known as the wilt disease. The virus appears to be responsible for the eventual collapse of most gypsy moth outbreaks. While the virus has been reared in the laboratory using gypsy moth hosts, and applied in the field with good results, high costs prohibit its operational use.

Control on a small scale can be carried out by removing egg masses and destroying them. Older larvae can be trapped beneath burlap flaps and destroyed (flaps are attached to the trunks of trees to collect larvae seeking shelter). Gypsy moth can be controlled with either chemical insecticides or *B.t.*. Two applications of *B.t.* are recommended because the hatch of egg masses in the spring is staggered and *B.t.* breaks down relatively quickly in the environment. Applications of *B.t.* are timed to coincide with 50% expansion of oak foliage.

WHITE PINE WEEVIL (*Pissodes strobi*)

The white pine weevil (WPW) is the most serious pest attacking eastern white pine in North America. While white pine is the preferred host, WPW will also attack all the common spruces and pines. The WPW is native to North America, with its range closely approximating that of the eastern white pine.

The WPW has one generation per year, overwintering as an adult within the litter beneath infested trees. Adults emerge in early spring and move to the terminal leaders of host trees, where they begin to feed and mate. Adults feed on the inner bark by puncturing the outer bark tissues with their snout. Eggs, approximately 100 per female, are deposited in slits made on the terminal leader. Females may deposit eggs on more than one leader. The eggs hatch in 1 to 3 weeks, with larvae initially boring inwards, and then tunnelling downwards, feeding on the phloem. Larvae are commonly arranged in a ring formation, so that the terminal leader is eventually girdled. Pupation occurs within the leader, and the adults emerge in late summer. Before overwintering, adults commonly feed on the lateral shoots of the upper crown.

Damage results from the feeding habits of both adults and larvae. While damage attributable to adult feeding (small puncture wounds that ooze resin) is negligible, feeding wounds may allow entrance of fungal pathogens. Damage due to larval feeding is more serious. It can cause a loss in merchantable tree volume of up to 40%, and devaluation of lumber quality. When larvae injure or kill the terminal leader, the growth form of the tree is affected by creating forked or crooked main stems. Trees may be subjected to repeated attack for several years. WPW damage does not result in tree mortality, unless the more vulnerable seedling stage is attacked. Symptoms of WPW damage include adult feeding wounds on the terminal leader, drooping or death of the terminal leader, and crooked or forked main stems.

In Ontario, outbreaks of WPW have been reported almost every year since 1930. The constant threat of either WPW attack, or infection by white pine blister rust, has had serious management implications with regards to the regeneration of white pine in Ontario. As a result, the regeneration of white pine by traditional plantation methods has been largely avoided. In the last twenty years, several occurrences of WPW attacking other pine and spruce species have been recorded. Young plantations of jack pine, white spruce, and black spruce have suffered damage, with up to 30% of the terminal leaders being attacked in a given year.

Control of WPW by the use of chemical insecticides is difficult. Terminal leaders may be drench-sprayed in spring time when adults are active, using a moderately persistent insecticide, such as methoxychlor. Because the larval stage is in a protected location, it cannot be controlled with the use of conventional contact or stomach insecticides. Trees that are infested should be hand pruned in mid-July to promote the development of a new terminal leader. Infested leaders should be destroyed by burning or other suitable methods, to help reduce WPW populations. Silvicultural methods that encourage shading of young conifers will help to reduce their susceptibility to WPW attack. To promote shading, conifers can be either planted with fast growing hardwoods that will quickly provide a cover, or conifers may be planted under a nurse crop of hardwood trees.

SUGAR MAPLE BORER (*Glycobius speciosus*)

The sugar maple borer (SMB) is one of the most damaging pests of maple in Canada. Sugar, red, and silver maples are subject to attack by this *Cerambycid* beetle. The SMB is thought to be native to North America, with its range closely coinciding with that of its maple hosts. Trees growing off-site or undergoing other stresses are predisposed to attack by SMB.

The life cycle of the SMB takes two years to complete. Eggs are deposited, usually on the host tree trunks, during mid-summer. Upon hatching, the larvae burrow beneath the bark and make tunnels across the grain as they feed on the surface of the sapwood. Larvae overwinter the first year inside a small cell within the wood. The following spring larvae begin feeding on the sapwood surface parallel to the grain. The second winter is spent in a cell that is located approximately 10 cm within the wood. Pupation and adult emergence occurs the following spring.

The main damage caused by SMB is attributable to larval feeding, as adults only feed on the tender bark of twigs, causing little damage. Larvae are usually found within the lower 9 m of the trunk, which is the most valuable part of the tree for lumber purposes. By reducing sap circulation, larval feeding tunnels affect tree vitality. Lower vitality may possibly result in branch mortality and tree decline. Tree mortality may result from the combined actions of as few as three or four larvae. Larval feeding tunnels, and the associated stain and decay, reduce the volume and value of lumber that can be sawn from infested trees. In addition to the reduction in wood quality and quantity, tree trunks damaged by SMB often break during storms at the point of attack. The presence of SMB is indicated by large swellings of the bark, that later crack open to form a wound.

The SMB is very difficult to control in any setting but direct impossible in the forest setting. In an individual setting, larvae may be killed by inserting a wire into their feeding tunnel, and pushing the wire to the end of the tunnel. Larvae may also be killed by injecting a fumigant into the tunnel, and then sealing the tunnel with grafting wax. An insecticide with moderate residual activity can be applied to the trunks of host trees, in order to kill ovipositing females. Infested trees or limbs should be removed and burned prior to the emergence of adults.

From a forest or silvicultural perspective, the only alternatives are management to reduce stresses on individual trees and ensuring that trees are healthy and rapidly growing. During management, attempts should be made to regenerate other species where it is a poor maple site and damaged or unhealthy trees should be removed from the stand during partial cuts.

FOREST TREE DISEASES

The concept of a disease in plants is an abnormal condition in a plant caused by an outside agent. The outside agent can be either biotic (a fungus, bacteria, virus or mycoplasma-like organism (MLO)) or abiotic (drought, climate or soil chemistry). Symptoms of disease include abnormal growth or development, discoloration, and necrosis or death. In order for a disease to occur, three things are necessary; a susceptible host, a causal agent and the correct environmental conditions for transmission. Depending on the disease and plant species, any plant is susceptible to a disease but any stress on a tree will greatly increase its susceptibility to other diseases. Stresses can be the result of any number of factors including: intense competition, low nutrient status, poor drainage, trees growing off-site, insect defoliation and changes in anything that affects the tree. When a tree dies or is cut, subsequent changes in microclimate, soil moisture and understorey vegetation could cause stress to its neighbouring trees and make them more susceptible to disease.

Diseases can be classified as either primary or secondary pathogens. Primary pathogens will attack a tree directly and cause a disease like chestnut blight, white pine blister-rust or tar-spot on maples. These diseases will attack any tree of a susceptible species. A secondary pathogen is one which will attack a tree that is already weakened by something else. An off-site sugar maple that was defoliated by forest-tent caterpillar and subjected to air pollution may die of Armillaria root rot. Armillaria was a secondary pathogen that attacked after the tree that was stressed from other factors. In other words the tree was predisposed by the other factors to attack by Armillaria.

TYPES OF DISEASES¹

A few broad types of forest diseases are described here. This list is incomplete and there are many types of diseases that are not described.

Stem diseases

Stem diseases occur on the trunk, branches or twig of a tree, although some diseases that occur only on shoots and twigs are often included with foliar diseases. Stem diseases are caused by the formation of lesions (dead areas) or cankers on the bark/cambium tissues. These cankers can vary widely in appearance and can form obvious circular or elliptical growth patterns, or appear as an abnormal growth in the bark. Cankers can be caused by abiotic causes like southwest injury (sunscald), pesticides or lawnmowers but are most often caused by a pathogen.

Wilts

Wilt diseases can infest a tree through the branches or the roots and once inside the host, the pathogen remains in the vascular system until the tree dies. They are generally disseminated through the vessels in the outer rings of xylem and cause increased loss of functional xylem (and wilting). Wilts can live on the host after it has died, providing a source of inoculum to spread the disease through the soil or by insects. This is also important in the transport of wood products. For example there are restrictions on the shipment of oak lumber to Europe that may carry oak wilt, shipments of oak from certain areas must be fumigated or it cannot be shipped to Europe.

Root rots

Generally root rots are secondary pathogens that are usually saprophytic and commonly found in the soil or in decaying plant materials. Any roots are susceptible to attack by rots, but trees of low vigour are most easily infected. Some disease fungi penetrate directly into healthy roots, but most infection occurs through root grafts (where roots grow together), injuries or where the tree is unhealthy or predisposed to infection. Once the fungi is established, it progressively kills the roots by girdling and feeds off of the dead root. Root rots can become a problem in forestry after a stand has been cut where the pathogen population can build up on the roots of the cut trees, and where trees are weakened by environmental stresses. Trees growing off-site, in urban areas and where they are subject to nutrient or moisture deficiencies are predisposed to root rots.

Declines

Decline diseases refer to a broad scale decline of a species often result from a complex of factors. They can often be brought on by changes in climatic conditions (drought) or other environmental factor (acidity of precipitation), and attack by an insect or disease organism. When

¹ The types of diseases has largely been adapted from Tattar (1978)

trees are weakened by these predisposing factors, they are often killed by a secondary pathogen like Armillaria root rot. Decline in red spruce at high elevations in Appalachians has been commonly attributed to low pH (acidity) in precipitation or clouds. Sugar maple decline has been often attributed to a complex of insects (forest tent caterpillar, pear thrips or gypsy moth), drought, off-site conditions and acid precipitation. Ash decline has been a problem in southern Ontario and is caused by ash yellows and drought.

FIVE MAJOR FOREST DISEASES²

CHESTNUT BLIGHT

Chestnut blight is a wilt disease discovered in 1904 in New York City, apparently introduced from the orient on imported seeds or plants. From there, the blight spread rapidly through eastern North America throughout the natural range of American Chestnut (Castanea dentata). It reached southern Ontario in the early 1920's; by the late 1930's essentially all chestnuts were infected and dying. Forest pathologists could find no effective control. By 1950, hope for recovery of the American chestnut was abandoned for the most part.

Of the best known chestnut species, the American chestnut is the most susceptible to the blight and the Chinese (C. mollissima), the most resistant. The European chestnut (C. sativa) is intermediate.

Early attempts at controlling the blight involved crosses (hybridizing) with resistant Chinese chestnut to produce a tree with the desirable stem-form and nut qualities of American chestnut with the resistance of Oriental varieties. These efforts were largely unsuccessful but there has been more recent interest involving backcrosses. A recent discovery of several strains of the fungus infected with a virus has generated much hope. The infected fungi (hypovirulent strains) are much less virulent than the normal fungi. With the slower-growing hypovirulent strains, the trees are able to overcome the disease and continue to grow.

Disease life cycle

Infection usually occurs in fresh wounds that reach living bark. The spores are most often carried by insects but can also be spread by birds, rain or the wind. The hyphae grow into the bark forming cankers on the bark. Lesions on twigs or small branches often expand into larger branches or trunks. The canker grows until the tree is eventually girdled and killed.

Chestnut is a prolific sprouter. Meaning that when a tree is killed, the stump can continue to sprout for many years. This has kept the species from being totally wiped out, but also serves to

² The descriptions of these diseases have been taken from Sinclair et al. (1989).

keep the blight in an area. Chestnut trees have to become a reasonable size before they will produce nuts and they are often killed by the blight before that time.

The effect of chestnut blight on forests

The American Chestnut was once one of North America's most important forest trees. The wood, easily worked, durable and rot resistant, was used for interior trim, furniture and posts and rails for fencing. Some split rail fences constructed early in this century are still standing. The annual chestnut crop made it important to the forest community, providing a reliable food source for wildlife as well as early settlers. Although the nuts are smaller than other kinds of chestnuts, they are the most delicious.

The natural range of the American Chestnut extends from southeastern Michigan through southern Ontario to Maine, and south to Georgia. Chestnut commonly made up to 25% of mixed stands and formed pure stands on many dry ridgetops of the Appalachians. In southern Ontario, chestnut occurred throughout the Deciduous Forest Region (Carolinian Zone), but was most common on sandy soils and on well-drained slopes in Norfolk County and around Dundas. Because Ontario is at the extreme of the natural range of chestnut, the population of trees was discontinuous here and there are a relatively large number of surviving chestnuts in Ontario.

As chestnut grew well on dry sites, its loss from the forest was particularly catastrophic on those sites. Dry-site oaks and hickories have taken over the sites formerly dominated by chestnut, although they are not well-suited to the sites and their wood tends to be poor quality. Wildlife populations dependent on the reliable mast production were decimated and populations of deer, bear and turkeys were drastically reduced.

DUTCH ELM DISEASE

Dutch elm disease is a wilt caused by the fungus Ceratocystis ulmi. The disease entered North America in elm logs from Europe before 1930 and has spread by elm bark beetles and by people moving wood, to most places where elms are grown in North America.

Spores of the fungi are picked up by the native elm bark beetles (Hylurgopinus rufipes) or the European elm bark beetle (Scolytus multistriatus) as they exit dead elm trees they have developed in. New trees are infected as the adults feed on the twigs European elm bark beetle (S. multistriatus) or the bark of branches and small trunks (H. rufipes). From the point of inoculation the disease moves upward and downward killing all or part of the tree. The dead branches or trunks are then used as breeding sites for the bark beetles. Where elms are growing closely together the disease is often transmitted through root grafts to neighbouring trees. People moving wood from dead elms without removing the bark also facilitate the spread of the disease as the beetles and inoculum are moved wood.

There is no effective control for the disease except for individual trees. The only effective way to prevent the spread of the disease is by removing the bark, burning or burying infected or dead trees. Most native elms are highly susceptible to the disease, but there is a resistant individuals occur even within susceptible species. With this genetic resistance and the tendency for elms to produce a lot of seed at an early age, there is hope that elms will eventually recover from the disease.

The effect of Dutch elm disease on forests

The white or American elm (Ulmus americana) was a dominant tree in the urban landscape before the Dutch elm disease occurred. It is a beautiful and hardy tree that grew well in cities. Since many of the urban elms grew in rows along streets, the disease was rapidly transmitted down the row via root grafts. Within a few years all of the elms in a city were usually killed.

In the forest, white elm is known as a wet site species, often found in wet meadows, pastures and wetlands. On many wet sites, the forests were held together by elms which would grow to a large size, changing the microclimate and allowing other trees to prosper. With the demise of the elms, other species like white cedar, white birch, balsam poplar and green ash dominate wet site forests. Unfortunately these other species do not develop the stature or size that white elm does and the stands tend to blow down or fall apart at a relatively early age.

WHITE PINE BLISTER-RUST

This devastating rust disease is caused by a Eurasian fungus Cronartium ribicola, that was introduced on diseased planting stock from Europe in the early 1900's. It has spread throughout the range of susceptible (soft, white or 5-needle pines) in North America.

The disease spends part of its life cycle on an alternate host (Ribes or gooseberry). Infection in white pine begins when basidiospores from Ribes are blown onto pine needles in nighttime during cool, wet weather between midsummer and early autumn. Infection of the needles cannot occur except during these specific environmental conditions. The basidiospores germinate on wet needles and the parasite enters through the stomata, grows into the twig or young leader. The fungus grows about 8-cm per year along the branch causing discoloration or swelling. Aeciospores are then produced that can be airborne and transported long distances to infect Ribes. The disease then grows for a season on Ribes, producing the basidiospores in the late summer/early fall that reinfect the white pine and complete the life cycle.

Not all infections are lethal and there is some resistance within susceptible species. The risk of lethal infection is greatest in small trees as the distance from the needles to the main stem is shortest. When the fungus reaches the main stem, the tree is usually girdled and dies from that point up. When infection occurs on larger trees at the top of the canopy, the branch is often killed before the disease reaches the main stem.

For many years it was attempted to control the disease by eradicating Ribies. However, this strategy was unsuccessful since Ribies is very common and the disease can be transmitted over several kilometres. Blister-rust is still a problem in southern Ontario but does not often wipe out a stand or plantation. A certain amount of losses or mortality is usually expected from blister rust.

The effect of white pine blister-rust on forests

Economically and ecologically, white pine is a very important tree species. The disease caused a shift away from managing for the species however in recent years this has changed. In the Great Lakes St. Lawrence forest region, the climate is not always suitable for transmitting the disease, and the white population in the Deciduous Forest Region and parts of the Great Lakes-St. Lawrence is discontinuous. Eastern white pine may also have developed. The effects of the disease have been greater on western white pine (Pinus monticola) which has shown little resistance to the disease.

BEECH BARK DISEASE

Beech bark disease is a devastating disease of American beech that results from sequential attacks of a scale insect and a number of fungi in the genus Nectria. The disease was first noted in North America in Nova Scotia near Halifax during the 1920's. Apparently the scale insect was imported on nursery stock of European beech, and it formed complexes with local fungi. Generally the scale moves at a rate of 15-km per year, followed after several years by the fungi.

The scale larvae crawl or are wind dispersed to a feeding site where they become established and cannot move. Colonies of the scale become prominent on the tree trunks as white cottony spots or patches. Some bark necrosis is caused directly by the scale, but most is due to the fungi that invade and kill bark stressed by the scale infestation. Once the fungi invade the tree, the scale disappears. The fungi forms cankers under the bark and after several years most or all of the tree will be killed. Larger and older trees are killed more easily than smaller ones.

Since European settlement a few hundred years ago, most forests have been high-graded repeatedly. In other words, the most desirable and valuable trees have been cut and removed. Because beech is very shade tolerant and tends to sprout, is susceptible to a wide range of relatively minor diseases, tends to have a lot of defect in for lumber production, and has wood with a number of undesirable qualities, it has led to high components of beech in many forests in Eastern North America. In many cases the beech is large, old and not necessarily in the best of health.

The effect of beech bark disease on forests

As mentioned above, many forests in Northeastern U.S. and Eastern Canada are predisposed to beech bark disease from poor harvesting and management practices. Where there are high beech components, the disease has catastrophic effects as it moves through as much of the beech is killed. In recent years beech has become more valuable economically, so this disease has

obvious economic impacts. Ecologically, it is much more significant. Since beech is one of the only mast (fruit or nuts) producers in the northern hardwood species association, its demise has serious impacts on wildlife populations that rely on it (squirrels, deer, bear and turkeys). Since the loss of chestnut, the main mast producers are beech, cherry and nut producing species like oaks, hickories and walnut. Many of these mast producers are intolerant species whose populations have been reduced in recent years because of the lack of catastrophic disturbance. Because of its tendency to be rotten and have cavities, the loss of beech may affect the availability of nesting or shelter sites for birds and animals.

REVIEW

1. Forest entomology is the study of the effects of insects upon forests, forest products, and the forest environment. Forest entomologists study insects in order to prevent the damage resulting from forest insects from reaching economic levels.
2. The impact of insect damage depends on the significance of the damage from the human perspective and is usually expressed in economic terms.
3. Trees have developed defence mechanisms to defend themselves against insect attack. Broadleaved trees may lose up to 50% of their leaves without observable effects on tree growth or general tree health.
4. Understanding the life cycle of a pest is important, since control strategies often only work against certain stages.
5. There are six basic control strategies available for the control of forest insects: mechanical, legal, cultural, biological, chemical, genetic and Integrated Pest Management (IPM), a combination of the six.
6. Trees may not be greatly affected by background or endemic levels of insects, unless they are weakened by other stress factors.
7. A primary pathogen will attack any tree of a susceptible species, and make it susceptible to secondary pathogens, which only attack weakened trees.

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Chapter 11

PRIVATE LAND FORESTRY POLICY IN ONTARIO ¹

Sheila Pease

AGENCIES AFFECTING WOODLOT MANAGEMENT

ONTARIO MINISTRY OF NATURAL RESOURCES

Ministry of Natural Resources (O.M.N.R), formerly known as Lands and Forests, has within its mandate managing Ontario's forest, and wildlife. Fish and wildlife habitat, fishing and hunting regulations, and protection of endangered species are all aspects of the wildlife part of the mandate. The ministry manages crown land, including provincial parks, for wildlife, timber, and recreation. Provincially run nurseries at Orono, St. Williams, Dryden, Swastika, Thessalon and Kemptville were established to supply trees for crown land plantations, agreement forests, and private land forestry. O.M.N.R. is a partner in several landowner assistance programs to help fulfil the forestry portion of their mandate.

Woodlands Improvement Act Program (WIA)

Since 1966, when the Woodland Improvement Act was passed, landowners in Ontario have been receiving direct financial assistance for reforestation and woodland improvement. Between 1966 and 1981 a total of over 15,000 agreements have been made with landowners. Of this total, 8,359 agreements have not yet run out. This program is changing.

Until now, landowners with 2 ha (5 ac) or more of land exclusive of buildings could enter into a 15-year agreement with the Ministry of Natural Resources (OMNR) for planting or thinning assistance. The agreement included a management plan developed by the OMNR and the

¹ Note that regulations and government programs are constantly changing, and some of those discussed in this chapter may already be out dated. For information on current forestry regulations and programs contact your local OMNR office.

landowner. In the case of landowners with lands to be reforested, they purchase the nursery seedlings from the O.M.N.R., and the O.M.N.R. either pays them to plant the trees or does the planting for them. Site preparation and early tending activities are also covered. In return the landowner agrees to manage the woodlot and protect the trees from livestock, disease, fire and insects. The owner is required to repay costs to the O.M.N.R. if the agreement is violated, or if the property is sold and the new owner is unwilling to assume the agreement.

Advisory Services Act Program (ASA)

Where district resources are available, the OMNR provides an advisory service to assist landowners in woodlot management and afforestation of idle land. Information on plans for reforestation of idle lands, windbreaks and shelterbelts is provided, along with management recommendations designed to meet the landowner's objectives. These objectives may include protection of woodlands, harvesting, or managing for wildlife habitat. Often a forester or technician will visit the owner to discuss forestry matters at the site.

For woodlands where harvest or thinning is appropriate, the OMNR can provide tree marking suited to landowner objectives at no charge. Trees to be removed are marked with paint spots and volumes are estimated for the marked trees. Advice on markets is available to those with saleable forest products. The OMNR can also provide a sample contract and advertise the sale to potential buyers. The landowner is responsible for making sure the contract is adhered to.

Provision of Forest Trees for Planting

Many farms contain cleared land unsuitable for agricultural crops. Very often this land will grow good tree crops and should be afforested. Since 1905 the Ontario government has been supplying subsidized nursery stock to landowners in Ontario. Currently, landowners with 2 ha (5 ac) of land exclusive of buildings or structures may purchase nursery stock from the OMNR to be used for windbreaks, shelterbelts or forestry purposes. The seedlings cannot be resold, given away, or transplanted for a non-forestry use.

Species frequently available include: white pine, red pine, jack pine, white spruce, tamarack, silver maple, white ash, red oak, poplar, Norway spruce, European larch, black walnut and black locust. Since the species vary from year to year, the farmer should check with the district M.N.R. office for current species availability. The price for all species of nursery stock is \$0.10 (1993) per tree plus a \$10.00 cover charge per order, although prices are subject to change at any time. There is a minimum order of 100 trees and a minimum order of 50 trees per species. Orders should be placed in the previous year, since stock is allocated on a first-come-first-serve basis. Most private orders are available for pick up or are shipped in the spring beginning around April 20th. Application forms for nursery stock are available from local ministry district offices or M.N.R. nurseries.

Natural Areas and Wetlands

The O.M.N.R. is the provincial agency responsible for wetlands and wildlife management and development policy. It is also responsible for the designation and protection of Areas of Natural or Scientific Interest (ANSI), and has an interest in activities that may affect them. Such areas may contain geological formations, vegetation, or wildlife that are unusual in some respect and warrant conservation. ANSI designation does not prohibit forest management activities that conform with other legislation (tree cutting by-laws).

Tax Rebates

Private land tax rebates are available under the **Ontario Conservation Land Tax Reduction Program**. The intent of this program is to recognize, encourage and support the long-term, private stewardship of special conservation lands. It provides property tax rebates on eligible land available to those landowners who agree to maintain these areas. The Ontario Managed Forest Tax Rebate Program, a rebate program designed to encourage landowners to manage their forests was dropped as a budgetary reduction measure in 1993.

Land eligible for tax rebate under the conservation land tax reduction program includes Class 1, 2, and 3 wetlands; areas of natural and scientific interest (ANSI); Escarpment Natural areas as designated by the Niagara Escarpment Plan; non-revenue producing Conservation Authority land; and certain conservation lands owned by non-profit charitable organizations, which do not fit into the above categories. The area of conservation must be a minimum of 0.2 ha (1/2 ac).

Application forms and more detailed information on both programs may be obtained from the Subsidies Branch at the following address: Subsidies Branch, Ministry of Municipal Affairs, 777 Bay Street, 12th Floor, Toronto, Ontario M5G 2E5 (Phone: 1-800-268-8959, (416) 971 8071). Have your property tax role number available when you call.

FORESTRY CANADA

Tree Plan Canada

Tree Plan Canada is a national tree planting and care program funded in part by Canada's Green Plan for a Healthy Environment through Forestry Canada (re-named Department of Natural Resources Canada/Forestry). The program is a six-year program which began in 1992 with the goal of fostering and encouraging the planting of up to 325 million trees. It allows Canadians to make a personal contribution towards offsetting the major environmental problem of global warming. A non-profit, non-government, charitable foundation called the National Community Tree Foundation had been created to manage the program.

Tree Plan Canada is based on partnerships. Financial assistance is available to qualifying partners for tree purchases and certain planting costs. The program also provides technical advice to assist partners in developing and implementing their projects. Partners can contribute labour, material, services or by sharing in their project's financial cost. Most importantly, partners must be prepared to

maintain and care for the trees after planting. Tree Plan Canada supports community based tree planting activities. Environmental groups, volunteer organizations, school groups, municipalities and community clubs or associations are all welcome to apply.

Planting projects are eligible if they support environmental objectives, are not for commercial or industrial purposes and have written authorization from the landowner. Eligible projects will then be evaluated against the following criteria: degree of on-going tree care and maintenance (this is a critical requirement); environmental, aesthetic or recreational benefits provided; extent of financial or in-kind commitment by partners; cost-effectiveness of the proposal; and level of community involvement and environmental awareness developed.

For more information please contact: Tree Plan Canada, Forestry Canada, 1219 Queen St. East, P.O. Box 490, Sault Ste. Marie, Ontario, P6A 5M7. Telephone (705) 759-5711, Fax (705) 759-5712.

Project Tree Cover

Project Tree Cover is a tree planting initiative for private landowners. Over the next five years, Project Tree Cover seeks to establish over 16 million trees on private lands in Ontario. This program is a partnership between Tree Plan Canada, and Trees Ontario, an environmental initiative of the Ontario Forestry Association. The partnership will forge Ontario's commitment to achieve Tree Plan Canada's planting goals, while ensuring the delivery of high quality tree planting projects which are sensitive to the needs of Ontario's private landowners.

Private landowners are encouraged to apply if they have at least 2 hectares of land which could benefit from the establishment of trees, are willing to provide long-term care and maintenance for planted trees and are not establishing trees for commercial purposes. The landowner is required to contribute either in cash, or in-kind, a minimum of \$0.20 per tree to offset the costs of site preparation, planting and tending. Project Tree Cover will provide technical expertise, tree seedlings, site preparation and tree planting services, and project monitoring to ensure quality control. A maximum of 8,500 trees may be planted per year on any given project. More information may be obtained from the Ontario Forestry Association: 150 Consumers Road, Suite 502, Willowdale, Ontario, M2J 1P9. Telephone: (416) 493-4611.

AGRICULTURE CANADA

National Soil Conservation Program (NSCP)

Agriculture Canada's objective in launching the permanent cover program of the NSCP was to encourage farmers, through a unique bidding system, to establish their own level of compensation for the permanent retirement, protection and maintenance of fragile agricultural land. For the purposes of the NSCP, fragile lands were defined as tilled agricultural lands subject to severe erosion caused by water, wind or tillage; or lands subject to flooding. Continued row crop production on these acreages often just does not pay. Farmers are better off concentrating their crop production efforts on areas having a higher potential for economic yield, at a lower environmental cost.

Permanent Cover II Program (PC II)

Permanent Cover II Program is basically an extension of the National Soil Conservation Program.

ONTARIO MINISTRY OF AGRICULTURE AND FOOD (OMAF)

Ministry of Agriculture and Food (OMAF) regulates farm produce under the Farm Products Grades and Sales Act for Ontario. Along with regulating farm activities, and providing agricultural technical advice, OMAF has at various times provided some technical and financial assistance for establishing windbreaks and riparian zones through windbreak programs, maple syrup production, soil and water conservation programs and, more recently, the land stewardship program.

MUNICIPALITIES

Counties and Regional Municipalities are local levels of government that can pass by-laws under the Trees Act regulating tree cutting, and under the Drainage Act regulating planting trees along municipal drains. They also control zoning and regulate woodlot/land severances and sales.

Townships and cities serve similar functions; however they can pass by-laws regulating tree cutting under the Municipal Act.

CONSERVATION AUTHORITIES

In 1946, an act was passed allowing the formation of a Conservation Authority (C.A.) for each watershed in Ontario to manage the water and related land resources in their watershed. A few Conservation Authorities were formed at this time, and the rest were established later. These agencies, in partnership with the province and member municipalities, have a mandate to control water flow, augment water supplies and maintain water quality. To achieve these goals, Conservation Authorities have constructed dams and reservoirs, and undertaken channel improvements and stream rehabilitation. They have input to drainage plans, lot severances, development permits, and any other activities that affect water flow or quality within their watershed. This includes activities on or near wetlands, floodplains, hazardlands and reservoirs.

Since water quality is affected by sediment, Conservation Authorities are interested in erosion control techniques and management practices that affect runoff. Some of these practices include windbreaks, buffer strips, cover crops, tillage systems, and waste storage.

Although Conservation Authorities were formed for water management purposes, they have been playing an increasingly prominent role in conservation. For example, streams are rehabilitated to improve water quality along with fish habitat. Also, in the interest of fulfilling their water quality and control mandate, Conservation Authorities may acquire hazard lands, swamps or wetlands that are part of the river system. The land associated with these projects is often used for other conservation purposes: some are reforested, some are maintained for wildlife as natural areas, and some are developed as public recreational areas.

Conservation Authority Tree Planting Service

Most Conservation Authorities also offer a tree planting service. Trees for forestry plantings are usually supplied by O.M.N.R. nurseries, although some Authorities produce their own stock. Stock produced by C.A.s costs more than O.M.N.R. stock, but is often available in a wider variety of sizes and species. Under this program the landowner pays for the trees and a portion of the tree planting costs. Some C.A.'s also have programs to produce and/or plant larger stock for specialty purposes like roadside trees, shade trees (not near buildings) or specialty plantings. Conservation Authorities generally plant smaller areas than OMNR, although this has been changing recently. Their programs often include a strong windbreak establishment emphasis. C.A.s are usually able to accommodate plantings like windbreaks and more elaborate planting schemes because of their experience with smaller area plantings and greater cost recovery.

ONTARIO MINISTRY OF THE ENVIRONMENT

The Ontario Ministry of the Environment (M.O.E.) is a provincial agency involved with anything affecting water quality and groundwater, which could include development of forested areas for urban use (septic systems) and potential pollution or erosion problems.

REGULATIONS AFFECTING WOODLOT MANAGEMENT

TREE CUTTING BY-LAWS

Counties or Regional Municipalities can pass tree cutting by-laws under section 4(1) of the Trees Act. The purpose of such laws is to regulate and restrict the destruction of trees in sensitive or significant natural areas, and to ensure the long term protection, health and productivity of woodlot ecosystems. Their purpose is not to prohibit tree removal, but rather to ensure that removal is done in accordance with good forestry practices.

These by-laws generally regulate cutting by setting minimum diameter limits for trees that can be cut for sale, without the advice of a forestry professional. The law focuses on large trees because these are trees the landowner is most likely to want to cut, and they represent the mature to overmature element of the woodlot that should be periodically thinned if smaller trees are going to reach full growth potential. Since some large trees are necessary to maintain the health and structure of mature stands, a density and basal area provision are frequently included in the law. Cutting formulae are kept as simple as possible to make the law enforceable.

The effectiveness of these by-laws varies widely by jurisdiction. Effectiveness depends on the strength of the legislation, the diligence and experience of the enforcement officer and the willingness of the municipality to prosecute violators. Penalties for violation (and successful prosecution) are generally fines and sometimes site rehabilitation. The Trees Act is currently under review and will be amended to include trees in urban municipalities. By-laws restricting tree cutting can also be passed

under the Municipal Act. The Planning Act also permits Municipalities to control cutting trees during the development process.

Before cutting, it is advisable to find out about the local tree cutting by-laws from the municipality.

LUMBER GRADING LAWS

Under the Ontario Building Code (OBC) and National Building Code most structural lumber must be graded according to the grading rules of the National Lumber Grades Authority (NLGA), and bear the grade stamp of a grading agency certified by the Canadian Lumber Standards Administrative Board. Recent changes to lumber grading laws make single-storey farm structures under 6000 square feet (not including farm home) the only exceptions to this regulation. Building inspectors will use design tables with visual references to help guide their decision about the quality of the lumber in question, and neither they nor local councils can be held liable for any damage or injury resulting from the use of ungraded lumber in these buildings.

In Ontario, the certified grading agencies are: the Ontario Lumber Manufacturers Association (OLMA) in Toronto and the Canadian Lumbermen's Association (CLA) in Ottawa. Larger sawmills usually employ a licensed grader. As well, both the OLMA and the CLA have licensed graders who travel to Ontario locations to provide the grading service (Phone: OLMA (416) 367-9717, CLA (613) 233-6205).

CUTTER-SKIDDER OPERATOR CERTIFICATION

Legislation brought in by the Ontario government in 1990 requires that anyone cutting wood, for commercial purposes, must obtain cutter-skidder operator training and certification. This includes everyone from professional loggers to farmers thinning their own woodlot and selling the firewood. The only exemption are landowners who cut wood on their own property, for their own use.

This legislation was introduced through the Ministry of Skills and Development in an effort to reduce the number of accidents in logging activities (O.M.S.D., 1989). Basically, it is an on the job training course, which consists of the skills required by a cutter-skidder operator for safe, efficient and productive job performance. Logging firms have someone on staff with authority to certify completion of training; however, companies with 5 or fewer people may obtain accreditation through private consultants, the Forest Products Accident Prevention Association, or other people authorized to sign that training has taken place. A list of local signing authorities is available from the Ministry of Skills and Development (phone 416-326-5605). New employees have 1 year to train, though most will complete training in much less time. Ministry of Labour Forestry Inspectors have the authority to issue a stop work order and levy stiff fines on those operating without proper training.

PESTICIDES ACT

Regulation 751 under the Pesticides Act requires farmers complete the Grower Pesticide Safety Course (GPSC) as well as pass the qualifying examination. This regulation was designed to provide education and training to improve the safe practices associated with the handling and use of

agricultural pesticides at both the grower and vendor level, thereby reducing the potential risk to applicators, bystanders and to the environment.

This regulation applies to the use of Schedule 1, 2 and 5 pesticides in both agricultural and forestry production (forestry production applies to all woodlot owners who have over 5 hectares in production). Many herbicides, insecticides and rodenticides that are used in such woodlot operations are classed as schedule 2 or 5 and will not be available except to the holder of the GPSC certificate. To obtain the GPSC certificate, contact your local OMAF office for the exact time and location of the next course.

REVIEW

1. Several assistance programs are available to landowners who wish to establish or manage a woodlot. These include the Woodlands Improvement Act, Advisory Services Program, tax incentives, Conservation Authority tree planting, and provincially run nurseries.
2. Tree cutting by-laws have been introduced in many municipalities, which require that the municipality be notified of any tree cutting activities. Since by-laws vary from region to region, the landowner should check with their local municipality before cutting.
3. Agencies affecting woodlot management include the following: Ministry Natural Resources, Ministry of the Environment, Conservation Authorities, Counties, Municipalities, Regions and cities.
4. Other regulations affecting woodlot management include provincial lumber grading laws and cutter-skidder operator certification.
5. The purchase and use of many pesticides requires certification obtained through the successful completion of the Grower Pesticide Safety Course.

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- Gallagher, P. 1992. Building code will formally okay use of ungraded lumber, *in* News, Ontario Farmer Eastern Edition. Aug 11. pg 18.
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Chapter 12

AGROFORESTRY

One of the earliest definitions of agroforestry described it as a land practice which increases the yield of the land through the incorporation of trees, forest plants, crops and/or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population (Bene *et al.*, 1977; King and Chandler, 1978). The concept of an agroforestry system implies ecological and/or economic interactions among the components of the system. In practical terms, especially in Ontario, agroforestry encompasses all of the uses of trees on farms, including practices like intercropping, windbreaks, shelterbelts, marginal land rehabilitation (plantations), woodlot management, woody biomass production, Christmas tree production and maple syrup production. In other parts of the world forms of swidden agriculture, which include shifting cultivation and slash and burn systems, are common agroforestry systems. Agroforestry practices are used all over the world and the definition of agroforestry simply identifies both traditional and modern land use systems with a forestry/agriculture interface. Some agroforestry systems fall at the edges of other disciplines. Windbreaks are an excellent example since they have not been considered a part of mainstream agriculture or forestry, but are considered within the mandate of agencies in both fields.

Since the 1970's, expanding production demands, increasing population pressures, resource degradation associated with modern agricultural practices, and low commodity prices have resulted in a re-evaluation of land use and development practices. The most compelling demands in terms of human needs, come from the tropics where high urban populations, sensitive environments, unstable governments and weak economies threaten the lives of many people and the existence of natural ecosystems. Modern systems like alley cropping have developed as a response to the use of traditional swidden systems on marginal sites like mountainsides or where population and economic pressures do not allow for sufficient fallow periods for fields to recover from the cropping period. This is where the term agroforestry was born and where agroforestry developed.

International Agroforestry

The potential of integrating agriculture and forestry in the tropics was recognized by Bene *et al.* (1977). They recommended the establishment of what is now ICRAF (International Council for Research in Agroforestry). Canada was, and remains, the largest contributor to ICRAF through the Canadian International Development Agency (CIDA) and the International

Development Research Centre (IDRC). ICRAF assumes a prominent role in agroforestry world-wide through policy development and technology transfer to governments, agencies and professionals. It is also renown as a source/library for agroforestry research and literature, and for the development of educational programs and extension tools. Agroforestry has always been an important component of agriculture. It is merely a new term for a range of traditional and modern practices involving trees, crops and/or livestock.

Temperate Agroforestry

Given the social, environmental and economic situation, the development and use of any land use practice in temperate North America will be different than in tropical or less-developed countries. In comparison to the critical human needs in many parts of the world, some uses of agroforestry systems may seem a bit absurd, but Ontario is not the Sudan, Indonesia or Peru. The type of problems in North America associated with resource management policy, farming technology, politics, labour costs and real estate values are realities alien to less affluent areas and must be dealt with on a regional rather than global scale. In developed countries, especially in urban fringe areas, traditional economic models for agricultural systems can break down. For example, the difference in value between a new subdivision with an established, vigorous oak tree in the front of each lot and the same area with no trees may be greater than the return on investment from an intensively managed walnut plantation on the same property.

Although less compelling in human terms, resource management, economic and environmental concerns are resulting in critical evaluations of rural land use in temperate regions. The agricultural community in southern Ontario has come under increasing criticism for practices that have accelerated soil and wind erosion, degraded soil structure, lowered water quality and reduced wildlife habitat and landscape diversity. Furthermore, low prices for farm products make it difficult for farmers to accept costs that may be associated with good stewardship; even though good stewardship is directly related to the long term productivity of agricultural land.

There is an obvious need for farming systems that can provide a vehicle for farmers to alter their land use patterns, are environmentally acceptable, and will provide opportunity for farm-land diversification. Agroforestry is one means of diversification of the farm enterprise, sustainable and profitable farming systems, and environmental conservation. It can help diversify the farm enterprise by providing opportunities to earn income by producing marketable crops like maple syrup, nuts or fruit and wood products, rather than relying on traditional commodity production (grain or livestock) as the sole income source. This means the farmer is less reliant upon a single product, which leads to a more stable cash flow.

Examples of how agroforestry offers opportunities for sustainable and profitable farming systems are the effectiveness of windbreaks for protecting soil and improving yields, and the profitability of intercropping for establishing plantations and orchards. Forest plantations on marginal agricultural lands are commonly used to rejuvenate a degraded site and provide economic and ecological benefits. Buffer strips, energy plantations, wildlife habitat plantings and forest plantations are examples of practices that provide environmental benefits while adding to the economic diversity of farms.

The role of agroforestry in Ontario agriculture varies from region to region and from farm to farm, depending on the soils, topography, climate, farm type and owner's objectives and interests. With the exception of woodlot management, agroforestry systems can be used for two broad types of applications: optimization or maximization of economic return, and

conservation or site rehabilitation. Depending on the situation some agroforestry systems can be designed to meet either or both of these objectives. Choosing the appropriate system depends on the landowner's objectives (Fig. 12.1).

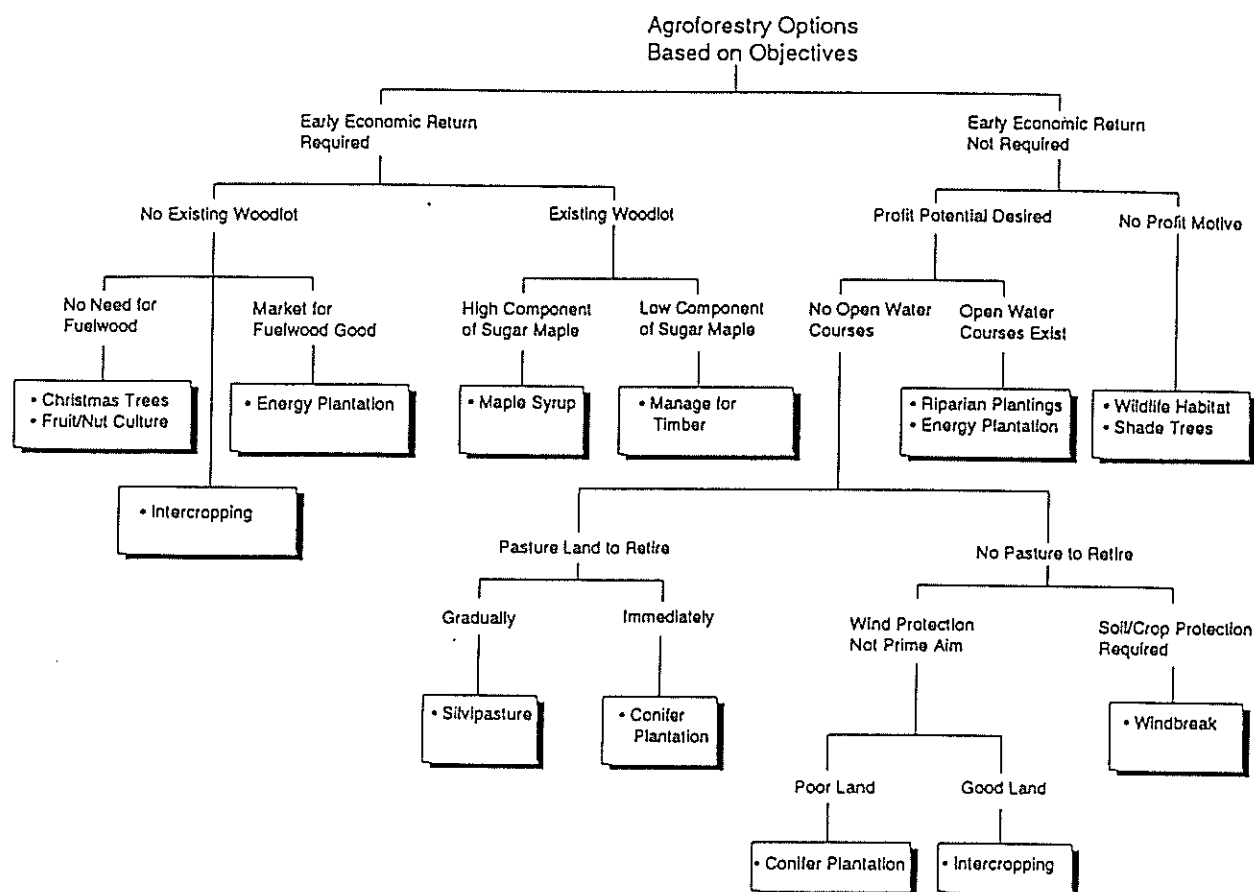


Figure 12.1. Matching agroforestry systems with objectives (Neuman, G.R.C.A.)

Why Trees?

Southern Ontario is one of the few areas in Canada where valuable hardwood tree species such as maples, oaks, walnut and ashes can be grown profitably for saw or veneer logs. Unfortunately because of the intensive agriculture practised in this region over the past 150 years, little land is available for growing trees. For example, in Wellington County, less than 6% of the original forest cover remains; in other counties in southwestern Ontario, this figure is less than 3% (Gordon and Williams, 1988). Although many hardwoods grow best on high quality soils, these sites tend to be dominated by agriculture. This leaves forest production to soils that are poor or marginal for agriculture.

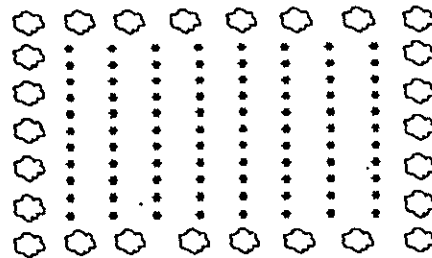
Because of the limited area producing hardwoods, Ontario has become increasingly reliant on imports of valuable hardwood logs and lumber. In 1982, for example, we imported 101,794,000 board feet of red oak lumber and logs for a value of \$26,164,000. Two years later the volume had dropped to 45,213,000 board feet, but the value had risen to \$33,335,000. The demand for domestic timber is present.

Types Of Agroforestry

Intercropping

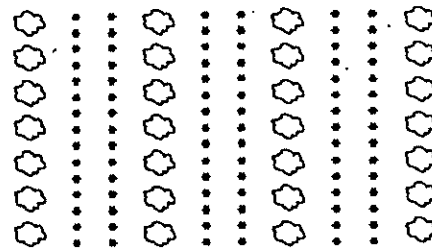
Intercropping is an agroforestry practice that involves growing trees and crops together in the same field. Trees can be planted randomly or in rows (Fig 12.2). A wide range of densities can be used to suit cultural, operational, or environmental considerations. In an intercropping scenario, trees are planted at spacings wide enough to allow a variety of feed or food crops to be grown among trees (for example 40 x 40 ft.; 12.5 x 12.5 m). While much of the recent development of agroforestry systems has taken place in tropical areas of the world, many systems have been utilized in, or adapted to, temperate regions.

Border / Windbreak



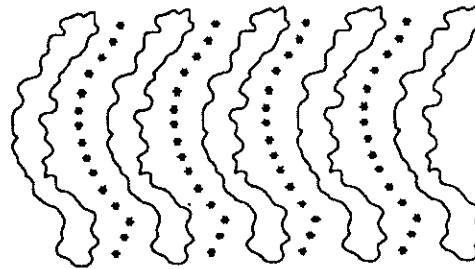
Intercrop

(Width and number of rows of crops and trees can vary)



Contour Alley Crop

(Alternate strips- usually short rotation coppice)



Random Mixture

(Unsuited to mechanization)

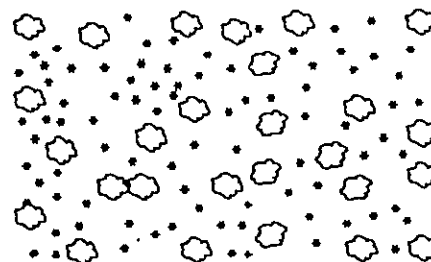


Figure 12.2 Intercrop field layout options.

Intercropping is an endemic practice world wide, but was not researched as a system until the field of agroforestry was established in the 1970's. Research and documentation on traditional intercropping systems is lacking, especially in temperate zones, but alleycropping systems (a more recent adaptation) are being investigated throughout the tropics. Since about 1980, there has been increasing amounts of research in temperate zones on intercropping with nut trees, especially American black walnut (*Juglans nigra* L.) with cash crops (Fig. 12.3).

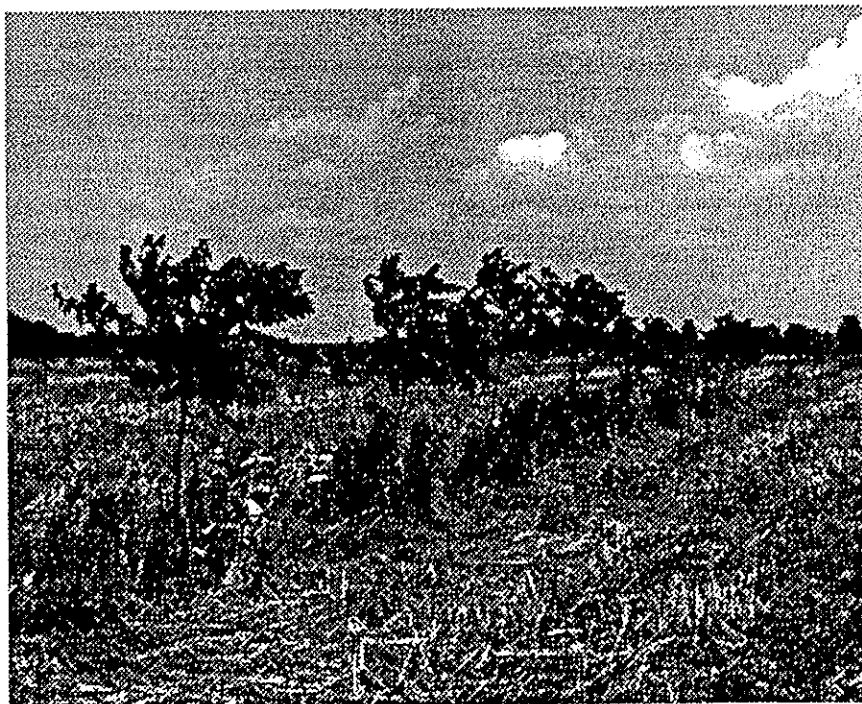


Figure 12.3. Black walnut/barley intercrop at Guelph, Ont. (Photo Don Hamilton).

BENEFITS OF INTERCROPPING

Some of the reported benefits of intercropping include improvements in crop yields and soil/water quality, and reductions in soil erosion. Intercropping also softens the impact of the long establishment time needed to derive income from a traditional fruit, forest or nut planting by providing regular income from a food or feed crop. Economic studies have shown that the profitability of intercropping is greatly enhanced by (and often dependent upon) the production of an annual tree-crop, such as nuts. However, the primary motive for many tree plantings is not necessarily to maximize profits (e.g., the rehabilitation of marginal or fragile lands). Therefore, it is important to look at intercropping as a land use system with an array of applications rather than simply growing black walnut trees with crops.

In agroforestry, intercropping has been viewed as a perpetual land use, or a system in itself. Crops are grown among tree seedlings; as the seedlings get larger, the crops change, the trees mature and are harvested, which begins the cycle again. However, intercropping is often used and seen as a clever way to get an orchard established or as a transition stage in a land use shift.

Intercropping can be used for high economic return and income diversification. When used on good farmland and with intensive management, intercropping has been shown to yield a

greater return than producing trees or crops separately. Intensive and integrated management on good land has been shown to be more profitable than producing trees, crops or livestock by themselves (Kincaid, 1982).

The large amount of imported lumber is indicative of the great demand for lumber needed for flooring, furniture, and veneer used in panelling and furniture. Intercropping is a method that can be used to increase domestic hardwood production while maintaining agricultural production.

An array of objectives and applications for intercropping have been described, however it is important to realize that some of the most useful applications for intercropping are within the realm of traditional agriculture and forestry. Although not prevalent, intercropping during the establishment years of orchards has been regularly practised with a number of tree species and annual crops (Fig. 12.4). It has also been demonstrated that intercropping systems are a realistic alternative to other methods of afforesting agricultural land, especially with hardwood species. The relatively newer phenomenon of black walnut intercropping appears to be an adaptation of the traditional "orchard establishment" scenario.



Figure 12.4. Tomatoes and cucumbers grown between peach rows during the early stages of orchard establishment in Vineland.

The point of this discussion is that intercropping should not be considered a rigid system defined by a particular tree species, crop pattern or tree spacing. Intercropping encompasses a broad array of plant combinations and cultural practices. Growing strawberries among peach trees is as much an intercropping system as growing soybeans among black walnut trees. Both systems warrant documentation and research.

ECOLOGICAL FUNCTION OF THE INTERCROP

An intercrop can perform two ecological functions with respect to the trees. The first is to act as a cover crop preventing the establishment of more competitive weed species. As much of an intercropped site is tilled and planted to a new crop each year, the crop prevents the establishment of perennial weeds, vigorous competitors to planted seedlings. Secondly, an annual crop will also compete differently than other vegetation and affect the soil and microclimate differently than perennial vegetation (forage crops or old field grasses). Intercrops enhance soil conditions and microclimate thus improving growing conditions for young seedlings. These effects are different with each crop since each crop develops at different rates, requires different cultural practices, and have different physiological characteristics (e.g., height

or biomass growth). For example, most crops will reduce windspeeds; but tall crops are most effective, and some crops will shade seedlings during the late summer reducing moisture stress. After trees have become established, the nature of competition changes so that the trees are less affected by the crop and will have a greater affect on crop productivity compared to earlier in the cycle.

It is difficult at times to distinguish between a cover crop in an orchard or plantation, and an agroforestry practice. The only real difference is that with a cover crop, the crop is not harvested but is ploughed under, mowed or left. If any of the crop is harvested or grazed by livestock then it is an agroforestry system. In ecological terms, there is little difference between the two and competition and weed control information regarding cover crops in orchard or plantations would also apply to an intercropping situation.

INTERCROPPED PLANTATION DESIGN

When designing an intercropped plantation the landowner objectives (economics of wood, nut and crop production; aesthetics, wildlife etc.), current cropping system, site and equipment considerations, all combine to determine the tree species, planting arrangement and cropping scenario that can be used. Tree species and crops planted to maximize economic return are different from those designed to maximize wildlife habitat, provide nectar sources for bees, or ultimately produce a mixed hardwood woodlot.

The layout of an intercropped planting is determined by landowner objectives and farm type. Normally, trees are planted in rows to facilitate planting and farm machinery. A cash-crop farmer may wish to grow demanding crops like corn on the site for as long as possible, which requires a wider between-row spacing (e.g. 12 m). On the other hand, a hobby-farmer who wishes to take the site out of agriculture or convert the field into a hardwood stand might choose a narrower between-row spacing (e.g. 5 m). Farm type can also influence planting configuration. For example, the equipment used on a 600-ha cash-crop farm would require more widely spaced tree-rows than would the equipment on a 10-ha specialty-crop farm. Within-row spacing will also affect the tree/crop competition, installation costs, and maintenance needs such as weed control, pruning and thinning.

The placement of tree rows can also play a role in the success of an intercropped plantation. Rows placed perpendicular to the direction of prevailing winds can act as windbreaks to protect crops and reduce soil erosion. McLean (1990) found that the row orientation affected the growth of black walnut and red oak seedlings intercropped with corn. He found that trees planted in an east/west or north/south orientation grew best. Ultimately, the shape of the field and topography of the landscape will dictate the orientation of tree rows.

In establishing an intercropped plantation, trees are planted similar to the methods described in Chapter 6: Plantation Establishment, but strict attention must be paid to row straightness to accommodate farm machinery and minimize damage to small seedlings that may be invisible to equipment operators. When establishing a plantation with corn, the field can be prepared using conventional methods for crop production including ploughing, fertilization, appropriate herbicide treatment and crop planting. In areas with long slopes, the tree rows should be located along the contours. Otherwise the tree rows can act as a ditch and cause gully erosion, especially when a mould board plough is used in subsequent years.

Silvipasture

Silvipasture combines livestock and tree production to attain the best combination of pasture growth and timber quality. These systems provide annual income from livestock while

trees mature. By comparison, integrated and intensively managed agroforestry systems have been shown to be more profitable than producing trees, crops or livestock by themselves (Harwell and Dangerfield, 1991). With controlled grazing, forage and livestock production can be quite compatible with certain cases of both tree establishment and mature orchards and plantations. Note that silvipasture is *not* pasturing animals in a woodlot nor allowing livestock uncontrolled access to plantations. Such practices must be avoided since they result in severe browsing and compaction damage to trees.

There are three basic types of silvipasture:

1. Planting widely spaced trees into pasture.
2. Using livestock to control competition prior to planting.
3. Using livestock to control competition in one or more stages of plantation development.

The first type can be used to ease marginal land out of active agriculture and into forestry much the same way as intercropping. The main advantage of using silvipasture over simple plantation establishment is that the landowner is able to utilize forages while the field is being converted to forestry. The grazing produces some economic return and helps to control competing vegetation as well.

Sheep and cattle are used in some areas of the western U.S. and Canada to control weed, grass, and shrub populations prior to planting trees. This can reduce planting and weed control costs, without concern for damage to the trees. Sheep have predictable feeding habits. They will exhaust preferred species before eating less palatable species; therefore, they will not browse seedlings so long as there is better forage available. When preferred forage becomes limited the sheep are moved to new pasture. Some spruce plantations in northern Ontario and western Canada have been successfully grazed in this manner. Often hardwoods and pines are susceptible to browsing until crowns are out of reach of the sheep (Fig. 14-5). Research on grazing mature nut and fruit orchards is being carried out, with varying degrees of success, in several regions of North America.



Figure 12.5. Controlled grazing of sheep among hardwood seedlings in southern Ontario.

Aside from browsing, proximity to predators, compaction, and rubbing are all concerns that must be addressed before adopting a silvipasture system. In British Columbia, domestic sheep must be kept away from big horn populations to prevent the spread of parasites. Wolves, mountain lions and grizzlies are other problems these farmers face when grazing young plantations. Livestock compact the soil around tree roots, which breaks roots and reduces water infiltration. This type of damage is minimized by not pasturing animals in one place too long. Cattle damage trees substantially by rubbing against them and breaking the branches (Fig. 12.6). Different techniques, including the use of repellents are being investigated to reduce this type of damage.

Many variations of silvipasture systems are being developed for use in all stages of plantation maturity. All of these systems require intensive management to minimize tree damage and optimize livestock and tree production. Grazing cannot completely replace other forms of weed control, nor is grazing compatible with establishment of all types of plantations at all stages of development. The potential of silvipasture is just beginning to be recognized in temperate regions and has a long way to go before it is generally accepted as a farming alternative.

Windbreaks

A windbreak is any barrier designed to reduce wind velocity near the ground. This discussion is restricted to windbreaks composed of shrubs and trees (Fig. 12.7). Shelterbelts are wide windbreaks consisting of six or more rows. The value of windbreaks has long been



Figure 12.6. Cattle often damage trees more through rubbing and trampling.



Figure 12.7. Porous white pine windbreak between crop fields in southern Ontario.

recognized, although their popularity has fluctuated over the past century. Many shelterbelts and windbreaks established on farms at the turn of the century have deteriorated to scruffy, weedy fence rows through age and lack of maintenance. Many others were removed to make use of wasted space and make fields better suited to large equipment. Now, with soil erosion becoming an increasing problem, windbreaks are being re-established and maintained.

Windbreaks can be adapted to serve many purposes beyond controlling soil erosion. The following is a summary list of windbreak uses.

- | | |
|------------------------------|---|
| Reduce soil erosion | - helps maintain soil integrity for crop production |
| | - improves water quality by reducing sediment, fertilizer and pesticide loading in watercourses |
| | - allows the cultivation of some soils which would otherwise be subject to degradation |
| Protect crops | - improves growth, yield and quality, which more than offsets loss due to competition next to the windbreak and loss of production space where the windbreak is planted |
| | - improves micro climate |
| | - reduces damage by wind blown sand, rain or hail |
| | - reduces desiccation making irrigation more efficient |
| Protect livestock | - improves health and weight gain |
| Protect buildings | - reduces energy costs through shading from the sun in summer and sheltering from wind in the winter |
| Keep driveways clear of snow | - reduces snow removal costs |
| Visual & audio screen | - blocks noise, dust and unpleasant scenery associated with some industries |
| Wildlife corridor | - provides wildlife with food, shelter, and a corridor to get from one covered area to the next |
| | - provides shelter for pollinating insects |
| Farm management Options | - diversifies income: timber/nut/fruit/fuelwood/fence posts/ maple syrup/Christmas trees/nectar for honey |
| | - improves aesthetics and property value by providing landscaping |

HOW A WINDBREAK WORKS

A windbreak works by disrupting wind flow across a surface. It will reduce wind speed appreciably in a cone like pattern on the downwind side of the barrier (Fig. 14-8). The downwind extent of protection is determined by windbreak height. Protection is provided for a distance of 8 to 12 h (h = tree heights) downwind of the windbreak. Due to air piling up before the obstacle, a distance of about 1 h upwind is also protected. The more dense the barrier, the

more protection it provides, but over a smaller area. As porosity increases, the area protected also increases, but the degree of protection decreases (Fig. 12.8). In most cases, a solid barrier is not as effective as one which lets a certain amount of air through, because of the increased turbulence towards the end of a very protected area. A cedar windbreak looks solid, but enough air can flow through it to make it suitably porous for crop, livestock and building protection.

Wind increases in velocity as it flows through large gaps in a windbreak. This effect is desirable if one is trying to scour away snow. However, if the purpose of the windbreak is protection, such scouring is undesirable. Scouring can be avoided by maintaining a relatively even degree of porosity across the length of the windbreak.

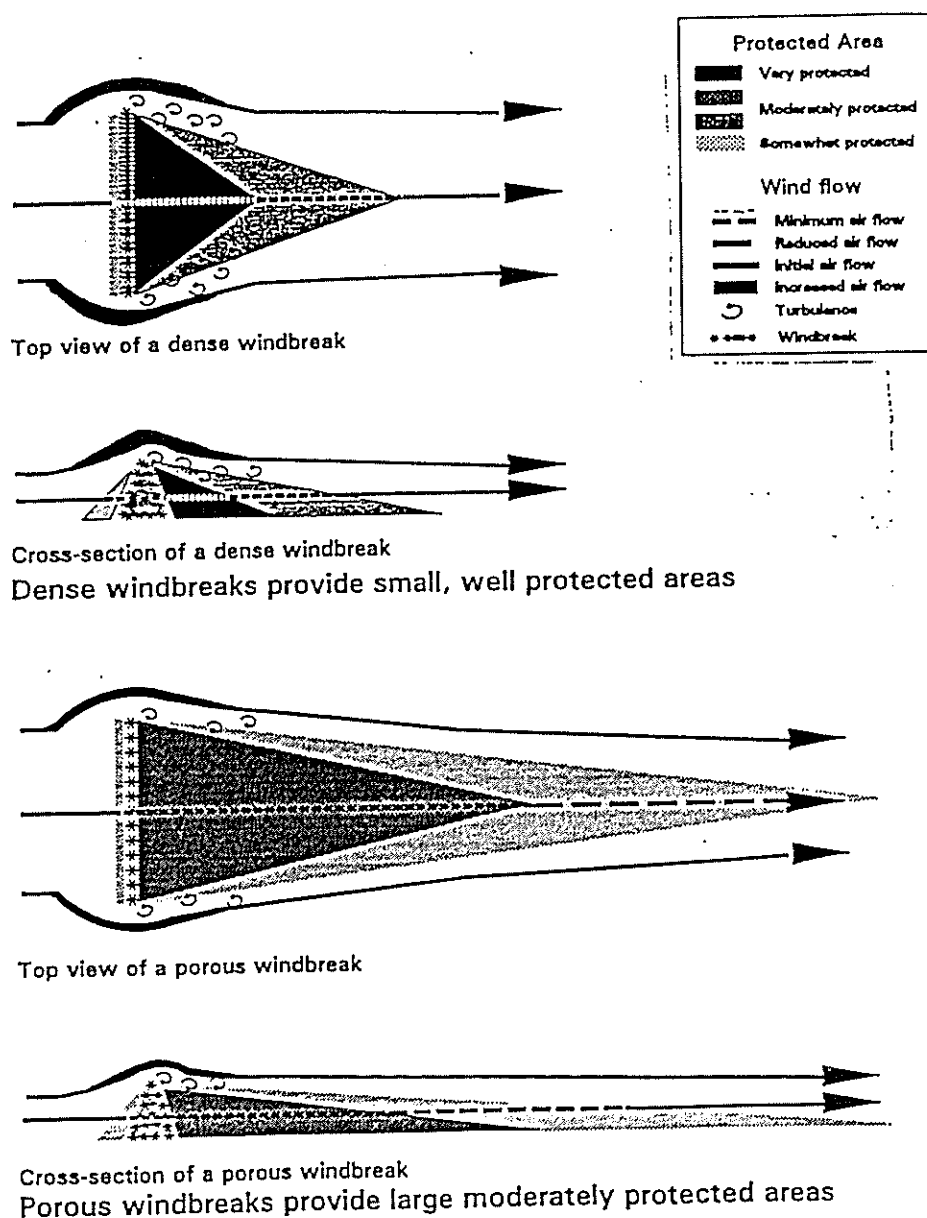


Figure 12.8. Wind flow patterns around a windbreak.

WINDBREAK ESTABLISHMENT AND MAINTENANCE

Careful consideration must go into planning an effective windbreak. A poorly located one can be worse than none at all. Often windbreaks can conform to current fence rows, or land uses; however, serious conflicts may arise with ditches, roadways, overhead lines, cables or tile drains. As a general rule, windbreaks should be planted at right angles to prevailing or problem winds (northwest in southern Ontario).

Windbreaks are established in the same manner as other plantations (See Chapter 6: Plantation Establishment). Many suitable tree and shrub species are available. The most commonly used trees are Norway spruce, eastern white cedar, white spruce, scots pine and Carolina poplar. Poplar is often planted as a second row because it grows very quickly and provides immediate protection. Unfortunately, it is short lived (20 to 50 years) and does not provide as much protection as conifers. Cedar is tolerant of harsh conditions and is often chosen as the windward row. Mixing deciduous and coniferous trees in a windbreak must be done carefully so as not to produce undesired gaps in winter that may lead to scouring. Species should be chosen on the basis of site conditions, hardiness, wind tolerance, density, height, crown spread, competitiveness, compatibility with adjacent crops and potential pest problems. Windbreak design, management and species composition must reflect its purpose.

Many windbreaks have been established in Ontario, but only a few of these are managed. Replacing dead trees during the early years is particularly important in preventing gaps through which the wind can tunnel and scour. Proper pruning can encourage dense foliage while reducing the number of fallen branches in the field. If scouring is desired, the lower 6 to 10 ft of branches should be removed. Information, on-site advice and planting assistance for windbreak establishment can be obtained from the local Conservation Authority or Ministry of Natural Resources office. Landowners should also check with the Ministry of Agriculture and Food regarding any current agricultural subsidies or incentives for windbreak establishment.

Buffer strips

Riparian, or streambank plantings, are buffers of vegetation along the banks of waterways (Fig. 14-9). They are ecologically important in that they serve to help reduce erosion, improve water quality, improve bank stability and enhance wildlife habitat. Currently, such buffer strips are usually non-existent or unmanaged. Many farmers work their fields as close to streams and ditches as possible so as not to waste space. Such practices promote wide, shallow streams with slow flow and high sediment loading, which result in wet fields and poor crop yields. Harvest from fragile land close to the water seldom makes up for the loss of topsoil due to erosion, nor does it justify the resulting damage to the stream. Often crop yield from these areas is very low due to flooding and soil movement. Farming marginal land is not profitable so it makes sense to use it in other ways. Setting aside a buffer strip can improve both crop yields from adjacent areas and the stream environment. Streams often cut through fields at odd angles, making them unusual shapes and difficult to cultivate. Establishing a riparian buffer strip offers the opportunity to square up fields without wasting land. Such a buffer strip can also be managed for timber, firewood, fruit, nuts, and/or wildlife habitat.

BUFFER STRIPS AS SEDIMENT FILTERS

One of the main benefits of riparian plantings is they can reduce the amount of soil washing from the field to the stream. If a stream collects sediment, the volume of water it can handle is



Figure 12.9. Riparian buffer strip along Washington Creek, Ont.

reduced, which increases the chance and duration of flooding. Along with the soil; bacteria, pesticides, fertilizer and other pollutants associated with agriculture get swept into the stream. As the normal stream bed becomes covered with sediment, fish spawning grounds and the habitat of stream bottom creatures becomes disrupted. Most of the sediment is farm topsoil. The erosion of this topsoil degrades soil structure and reduces crop yields. With the introduction of a buffer strip topsoil stays on the fields and crop yields improve. From a stream perspective, reducing sediment loading helps maintain water quality and stream depth. Also, minimizing sediment accumulation in municipal drains means lower maintenance costs.

BUFFER STRIPS AS NUTRIENT FILTERS

Buffer strips can also act as nutrient filters. Nutrients such as nitrates and phosphorous found in fertilizers create problems in streams. For example, excessive algae growth can reduce oxygen levels in stream water at night to below the threshold levels required for most fish and many aquatic insects. The result is destruction of stream habitat and spawning grounds. Trees along streams absorb nutrients that would otherwise enter the stream and then release them slowly as leaves and branches die. Stream-side trees also shade the water and may keep it cool enough to support valuable cold water fish such as trout.

BUFFER STRIPS AS WILDLIFE HABITAT

Riparian plantings can provide tremendous benefits to wildlife by providing food, shelter and water in one location. Trees and brush provide food and cover for many birds and

mammals. The wildlife species attracted will depend on the size of the buffer and the species of vegetation present. Ducks, geese and other shore dwelling birds may use the protected stream for feeding and the sheltered shore for nesting sites. A variety of songbirds use riparian areas as feeding grounds because of the abundance of insects that breed in and around streams. Trees that produce edible seed, berries or fruit will also attract a variety of bird species. Larger birds of prey, in turn may feed upon the small songbirds. A number of reptiles, amphibians and small and large mammals may also take advantage of the feeding opportunities and shelter provided by a riparian buffer strip. Snakes, salamanders, frogs, toads and turtles all may benefit from enhanced water quality and increased food supply. Mice, voles, squirrels, rabbits and other small mammals may escape predation within the cover provided by trees. Muskrats, otters and beavers will also benefit from a healthier stream environment. Food supply in the stream is increased and pollution caused by contaminated field runoff is reduced. With an increase in small animal populations predators such as foxes, fishers and weasels may also find ample nourishment opportunities.

PRODUCTS OF RIPARIAN PLANTINGS

Riparian strips offer many potential by-products aside from their main purpose of soil and water conservation. Small scale production of timber, fuel, wood, fruit, and nuts are all possibilities. As long as the soil conditions are right, and the groundwater is not stagnant, valuable trees such as ash and walnut will grow well. These can be managed for timber on a rotational basis, so that streambanks are not left susceptible to erosion by cutting all the trees at once. If conditions are not suited to these species, other species such as cedar may be grown and sold as timber or used as fence posts. Reforestation along water ways has the potential to compensate for historic losses of natural areas to agriculture and current losses to urban growth. Such plantations can also produce fuelwood, either for its own sake or as a by-product of thinning.

Energy Plantations

Plantations for energy production, either short rotation (producing biomass that can be burned or used to produce alcohol), or longer rotation (producing roundwood for stoves), can be used in areas that are marginal for crop production: riparian zones, poorly drained sites, and erodible or difficult to work fields. In addition to the economic production of wood for energy, these plantations can provide many of the benefits described above when planted in riparian zones. There is also a great deal of interest in using suitably located energy plantations as a way to dispose of municipal sewage sludge or manure. Such plantations have excellent potential to convert some of these nutrient-laden waste materials into a renewable energy source.

The conversion of any area from the cultivation of annual crops to the production of woody crops results in the accumulation of biomass, and the storage (sequestering) of carbon from carbon dioxide (CO₂). In an annual crop, all of the biomass is "recycled" each year without a net reduction in atmospheric carbon. Growing trees take in CO₂, which is changed and stored in woody tissue until the wood is burned or broken down by soil microorganisms. A typical mixed hardwood forest will store approximately 1.23 tons of carbon (or approximately 5 tons of CO₂) in permanent woody tissue per hectare each year (Hendrickson, 1992). With increased forest area and tree growth there may be a reduction of CO₂ in the atmosphere.

If the wood is burned for energy, as in a wood stove or a grain dryer, it helps offset the consumption of fossil fuels like oil or coal. *Efficient* burning of wood contributes less CO₂ to the atmosphere than fossil fuels because the carbon produced from wood burning was fixed from the atmosphere in recent years. Fossil fuel combustion releases carbon into the atmosphere that

was fixed eons ago. This is not to suggest that one windbreak or plantation will reduce global warming, but if agroforestry practices result in a significant shift in land use, the effect on CO₂ concentrations and global warming could be significant.

Swidden or Shifting Cultivation: A Traditional Agroforestry System

Swidden cultivation is a rotational agroforestry system where a forested or treed area is cleared and actively cultivated. Over time, as the soil becomes degraded, the area is converted to a progressively higher component of trees, or abandoned to forest, for a regenerative period (fallow period) of between 8 and 40 years (Vergara, 1987). After this time the cycle is repeated. The apparent waste of commercially valuable timber, soil erosion and stream siltation as a result of clearing has caused international agencies to view these systems as key to deforestation and ecological degradation. Campaigns have been initiated to eradicate this type of land use. However, some of this response is due to misunderstanding that developed because observers only witnessed the first few years of the cycle and also confused swidden systems with land use changes like clearing for commercial ranch land.

Only recently have swidden systems, particularly fallow fields, been recognized as an ecologically and economically significant part of a sustainable agricultural system. The intensity of use of the fallow field (regenerating forest) in swidden systems range from minimal and informal to intensive management throughout the cycle (Padoch and de Jong, 1987). Swidden systems can be productive and sustainable when they are kept small, and fallow periods (the time between farming episodes) are long enough for the soil to rejuvenate. Unfortunately, problems arise when population, political and economic pressures force farmers to shorten fallow periods, cultivate fragile land, farm larger sites and adopt modern farming techniques unsuited to the system. These problems, coupled with land clearing for speculative purposes, have combined to give swidden systems a bad name.

Adaptations of swidden systems can be credited as the roots of many agroforestry systems like intercropping, alley cropping and taungya. Padoch and de Jong (1987) described improved swidden systems in Peru, where crops were grown among young fruit trees. The trees were maintained through their productive years, and then cleared to start the cycle over. This scenario is remarkably similar to intercropping methods used with black walnut, fruit and nut trees in North America. The only obvious difference being the purpose of the tree crop: a recovery period in the tropics, vs. the main crop in North America.

Increasing demands from a decreasing land base has brought about the development of integral systems, such as intercropping and alley cropping. Instead of clearing a new field every few years, while the old one reverts to forest for rejuvenation, modern systems include a woody component from the beginning to help maintain site productivity. Economic pressures gradually force shorter and shorter fallow periods in the swidden systems, not leaving enough time for the soil to recover. Eventually, complete soil degradation results. Integral systems do not require the same sort of fallow periods, nor should they degrade the soil to a point requiring rejuvenation.

Review

1. Agroforestry practices were first recognized and developed in tropical regions. Agroforestry practices adapted to early farming systems in North America included using trees for windbreaks, live fences, wood products and maple syrup production.
2. Today the main purposes of agroforestry are diversification of the farm enterprise, sustainable and profitable farming systems and environmental conservation.
3. **Intercropping** involves growing high value trees among cash crops to obtain economic benefits from tree products as well as the field crop. Intercropping can be used to ease marginal lands out of cash crop production, generate income during the early stages of fruit and nut orchard establishment, and add ecological diversity that will benefit animal species as well as the human population.
4. **Silvipasture** is the production of livestock and trees together to gain profit from two different sources using the same piece of land.
5. **Windbreaks** provide wind protection for crops, soil, livestock and buildings while producing products such as timber, fuelwood, maple syrup, Christmas trees, fruit, nuts or nectar for honey.
6. **Riparian buffer strips** protect streams from sediment and excess nutrient loading, while at the same time allowing for the production of various wood products.
7. **Energy plantations** involve the growth of fast growing species to produce biomass which can be burned to heat buildings, dry grain or produce electricity or alcohol.
8. **Swidden cultivation** is a rotational agroforestry system where a forested area is cleared and actively cultivated until the soil becomes degraded, whereupon the land is allowed to go back to trees and a new area is cleared and cultivated.
9. Most of our knowledge of agroforestry in temperate areas has come from years of research and development in tropical areas of the world.
10. New technologies in intensive agriculture have lead to the removal of many trees from the modern farm. But with increasing problems such as soil erosion and other environmental concerns, farmers should consider the importance that trees may have in the future of their farm.

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Chapter 13

PLANTATION ALTERNATIVES

CONIFER PLANTATIONS

Conifers are popular species for plantations because they are relatively easy to establish, grow well under harsh conditions, and produce valuable timber or pulp wood. Special uses of conifer plantations include Christmas tree plantations, nurse crops, and as a component in naturalization plantings, where the objective is to re-establish native habitats or enhance conditions for wildlife. Red pine, white pine, scots pine and white spruce are the most commonly used species in southern Ontario, while jack pine and black spruce are most frequently planted in Northern Ontario. The species chosen depends primarily on site conditions, species value and available nursery stock.

In southern Ontario, conifer plantations have traditionally been used to retire degraded or abandoned agricultural lands. The objective being to rehabilitate the site and keep the area productive economically and naturally. When southern Ontario was first colonized by Europeans, the forests contained a large component of pine. Much of the large white pine was cut for ship masts and other timber purposes. Conifers tend to be earlier successional species than hardwoods. This means under natural conditions they would be some of the first species to become established in an open area, and be replaced by more shade tolerant hardwoods over time. This is the basis for using conifers as a nurse crop for hardwoods. The extensive planting of conifers in southern Ontario throughout this century has re-established a good source of timber for the production of softwood lumber. Conifer forests have played a large role in southern Ontario's past and will continue to have a place in its future.

MANAGEMENT

Thinning a stand properly is one of the most important aspects of maintenance. If a stand is thinned too much or too late, the risk of wind and snow damage is high. Diameter growth is inversely related to stand density; therefore, trees in a very dense stand will put on slow diameter growth until the stand is thinned. Systems of thinning vary with species, resource availability, and stand characteristics. Depending on initial spacing, often pre-commercial thinning of white and red pine will remove every third row at about age 25. The remaining middle rows, along with some trees from within rows, may be removed in subsequent commercial thinnings. OMNR foresters can provide advice and assistance with all aspects of plantation management.

HARVESTING

Conifer plantations may be harvested at about age 65, depending on the site species, and choice of end product. The method of harvest must be chosen in accordance with the purpose of the stand and how the stand is to be regenerated. For example, a seed source must be left if the stand is to regenerate naturally. If a seed source is not available, the site will have to be prepared and planted to start the cycle again.

CHRISTMAS TREE PLANTATIONS¹

Christmas tree farming on marginal land, which is unsuitable for the production of other agricultural crops, can be a profitable and sensible land use. Although the market for Christmas trees dropped through the 1970's it remains a strong industry. Most export sales are to the U.S. with a small percentage to the Caribbean. Nova Scotia, Quebec and New Brunswick produce most of Canada's export Christmas trees; although British Columbia and Ontario also have a small export market. The domestic Christmas tree market remains strong despite experiencing increasing competition from the U.S. and the artificial tree industry. Today's market is highly competitive and demands top quality trees, which can only be produced through professional management (Fig. 13.1). In Ontario, most Christmas trees are grown in plantations. In other areas, such as Nova Scotia, natural stands are managed for Christmas tree production.

¹ Adapted from: McPhee, H. 1982. A guide to Christmas tree growing in Ontario. Ontario Christmas Tree Growers' Association of Ont. Inc.. 58p.



Figure 13.1 Scots pine Christmas tree plantation.

CHRISTMAS TREE ESTABLISHMENT

Some of the important factors to be considered when choosing location and layout for a plantation include the following:

1. Distance from market - This will affect what type of marketing system that can be used and shipping costs.
2. Road systems - These must accommodate fire routes, maintenance equipment and harvesting. Road layout will depend on whether harvest is to be bulk or cut-your-own.
3. Water - Water must be available in case of fire and for irrigation, if desired.
4. Location of storage and handling areas for cut trees.
5. Plantation size - How large to make a plantation, and how large to make the compartments within a plantation must be decided well in advance of planting. Planning must allow for plantings in consecutive years to ensure a continuous supply of trees.

Choosing appropriate species is vital at the planning stage. As always, species must suit site and market conditions. A tree farmer should investigate the potential market for species suited to his land before choosing which trees to plant. The following is a list of potential Christmas tree species: white pine, red pine, scots pine, Douglas fir, balsam fir, white spruce, black spruce, Fraser fir, blue spruce, jack pine, Austrian pine and red spruce. In Ontario, both domestic and export markets are dominated by scots pine, followed in popularity by white spruce. A narrow regional demand exists for red, Austrian and white pine. Balsam fir is a traditional favourite in Eastern Canada, but has limited demand in Ontario. The cultural management (thinning, shearing and pruning) of wild balsam fir on private land produces enough trees to supply the demand for this species in the immediate future.

Planting a variety of species has several advantages:

1. Workload is spread more evenly through the year, since pines must be sheared and pruned in mid-summer and spruces and firs can be done during the dormant season.
2. Offering the customer a variety is usually an advantage at the marketing stage. This does depend on who and where are your customers.
3. Problems associated with a monoculture are reduced. Diseases and insects are usually species specific and are not as apt to attack an entire plantation, if a mix of species is used.

Establishment of a Christmas tree plantation is basically the same as for any other plantation (See Chapter 5 - Plantation Establishment). Spacing tends to be wider than for other conifer plantations to encourage healthy branches all the way to the ground. Intense management, including weed control, pruning, and shearing are necessary to produce a quality product. The manager must realize this and also be alert to recognize insect and disease problems at an early stage and take appropriate action.

MANAGEMENT OF NATURAL STANDS

A young, accessible stand of natural trees can also be managed to produce top quality Christmas trees. They must be thinned so they will be about 2 m (6 ft) apart when they reach market size. This requires considerable judgement because of the wide range in size and age of trees in natural stands. Crop trees must be chosen carefully. The rest must be removed as close to the ground as possible to make walking easier. Once the stand is thinned, management becomes similar to that of a Christmas tree plantation. A properly managed stand of naturally seeded trees can produce an annual crop of good quality trees.

PRUNING

Commercial Christmas trees must be pruned and sheared annually from the first growing year through to the harvest. This is done to increase foliage density and improve shape. Pruning and shearing are demanding since they must be done by hand within a certain time frame to ensure maximum bud production. Large operations may require large numbers of workers to complete the job within the optimum shearing period.

Pruning refers to the selective removal of whole branches and twigs. Shearing is a form of pruning which controls tree shape through trimming the tips of the branches (Fig. 13.2). Techniques and timing for shearing vary with species and growing conditions, particularly when developing density of foliage. Thus, nurseries and established tree farms are important resources for the new grower.



Figure 13.2 Shearing 6 year-old Scots pine with a pruning knife. (Courtesy of OMNR.)

HARVESTING AND MARKETING THE CROP

Christmas tree crops may be marketed in a number of ways and the sales method will be determined to some extent by the volume of production and location of the farm in relation to urban centres. Farms producing large numbers of trees generally establish wholesale market outlets. The smaller grower located reasonably close to a large city may find it profitable to retail

the trees, or use a cut-your-own (choose-and-cut) system. In a cut-your-own system, the customer goes into the plantation and cuts down the tree of their choice. In some instances, it may be advantageous for a group of small producers to pool their crops and supply one large wholesale order. In any case, a sales plan must be established well before the first harvest. Unsold crop trees can be carried over to the following year if left standing in the field, but an unsold pile of cut trees is a total loss to the producer.

Except in a cut-your-own system, the spruces and firs are usually cut from mid-November on into December, if weather conditions permit access to the plantations. Early frosts tend to yellow the foliage of Scots pines, so they tend to be cut, processed and piled before the first week of November to preserve the blue-green foliage colour.

Once trees are cut, the lower branches are removed to make a clean handle. The accepted grading standard in Ontario requires that one inch of clean trunk, or handle, should be provided for each foot of tree height. Thus, a six foot tree should have a six-inch handle. Any dead leaves and debris are then shaken out of the trees before they are graded and baled for shipping.

Christmas Tree Grades

Regulations for Christmas tree grades have been in place since 1965 under the Farm Products Grades and Sales Act for the province of Ontario. Grading is based on several things including branch spacing and quality, foliage colour and density, tree shape, stem straightness, mechanical damage, presence of lichens or other foreign material, and other defects. As tree grade improves, tree value increases. While grading trees is not mandatory, if a grower is to manage a plantation for valuable trees, a working knowledge of these standards is essential.

Baling Trees

Baling involves pulling the tree through a funnel to compress the branches and wrapping it with twine or encasing it in a sleeve of plastic netting (Fig. 13.3). This protects the foliage and branches from damage during handling and shipping, and permits loading of greater numbers on trucks, transports or railway cars. Baling and proper piling of the trees help minimize moisture loss and ensure the trees arrive in good condition.

Christmas tree growing can be an economically and environmentally sound land use option. However, like any other enterprise, good planning and dedication is essential to its success. The Christmas tree industry is very competitive and high quality is demanded by consumers. Thus, income potential from a few unmanaged trees on the corner of a farm is very limited. However, income potential increases substantially if the trees are pruned and tended.

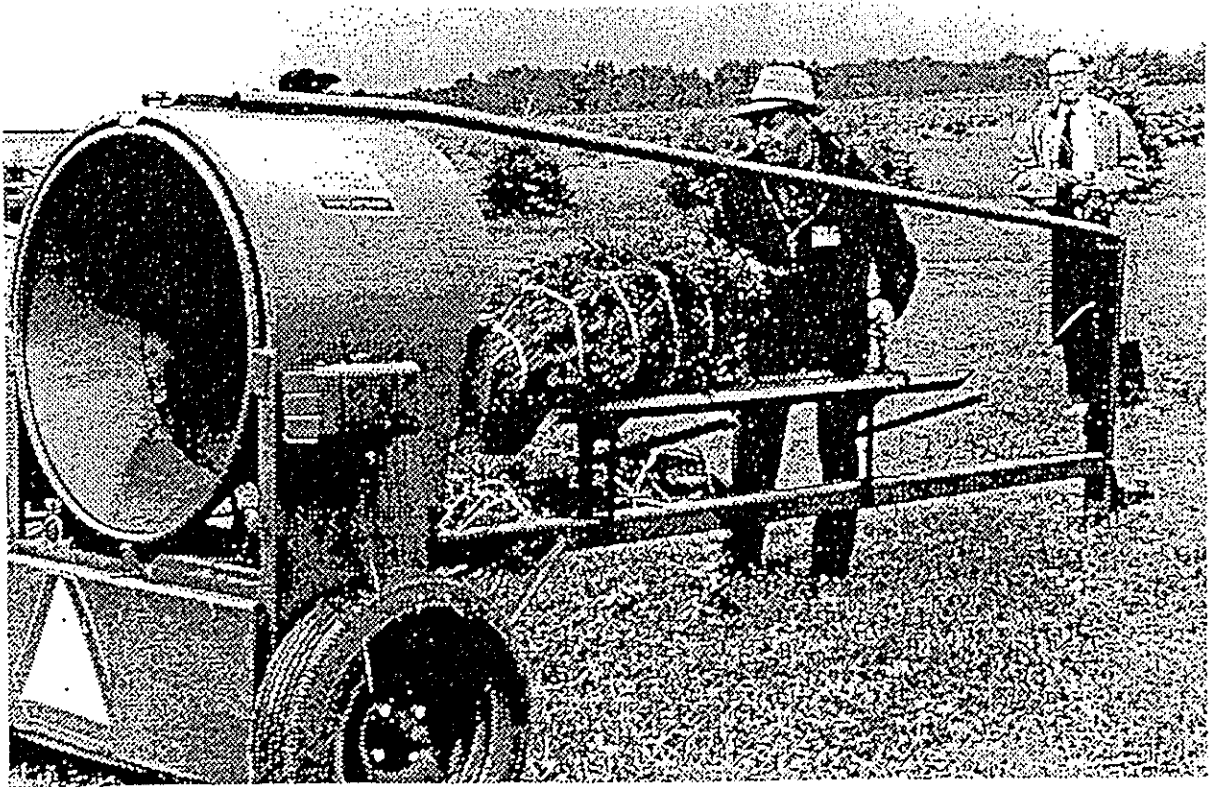


Figure 13.3 Christmas tree baling at a farm near Kempville.

FRUIT ORCHARDS

Fruit production is beyond the scope of this course and is only briefly mentioned here to make the reader aware of its potential in agroforestry. Fruit orchards by themselves are not considered agroforestry systems; however, they become agroforestry systems when combined with another form of agriculture. Intercropping vegetable or cereal crops between the rows of trees is definitely a form of agroforestry, and is commonly practised during the first few years after establishment. Under special circumstances silvipasture may be used in managing orchards. Both intercropping and silvipasture in orchards have usually been overlooked as potential agroforestry systems to the extent that many remain undocumented, much less researched. Recognizing these as agroforestry systems is important, since they offer a wealth of information that can be applied or adapted to new systems.

ORCHARD ESTABLISHMENT

Orchard establishment is similar to the establishment of other plantations (Chapter 5 Plantation Establishment), but more intensive due to the sensitive nature of fruit trees and the high overhead associated with fruit production. Plantation layout must allow space for all necessary equipment and harvesting operations. Extra care is also required for site selection both in terms of climate and soil conditions.

A new grower must assess both site and market conditions before selecting appropriately from the many species and varieties available. Apples, peaches, cherries, pears, apricots and plums are some of the tree fruits grown in Ontario. Species and cultivars vary in hardiness, adaptability, spray requirements and fruit characteristics. Local nurseries, OMAF horticulture crop advisors, and grower organizations are good sources of information.

HARVESTING

Harvesting vegetables or cereals from between tree rows is done in the traditional manner, but with care not to damage the trees. Methods of harvesting and marketing fruit vary with species, distance to market and size of orchard. Mechanical pickers may be an option for large scale operations; however, most orchards rely on seasonal help for harvesting. Pick-your-own is an option many orchards are adopting. While labour costs are reduced with this system, damage to trees during harvest tends to increase. Publications are available from O.M.A.F. all aspects of orchard production, which includes establishment, pesticides, diseases, weed control, harvesting, fruit storage and other aspects of orchard management.

NUT PLANTATIONS

The principle of nut production is similar to that of fruit production. Traditional soft fruit orchards have climactic and soil requirements similar to some of the hardier northern nut cultivars. Nut production has certain advantages over fruit production in that nut trees require less pruning, nuts are not as delicate, they can be harvested by mechanical shaking and nut trees require less spraying. However, Ontario nut production is a relatively new specialty crop with definite but limited production potential. The Ontario climate cannot support a nut industry capable of competing with the high volume groves of the southern States; but it can support a small cottage industry by catering to the gourmet market's demand for freshness.

Commercial production of nuts in Ontario has gained in popularity since the mid- 1980's, when hardier nut tree varieties were developed. These varieties vary tremendously in nut characteristics, disease resistance, and nut production. The most promising species are given in Table 13.1.

BLACK WALNUT

Black walnut is the only species which is dealt with in detail here because of its importance as an agroforestry species in Ontario. Black walnut is native to parts of southern Ontario and highly valued for its nuts and timber. Walnut wood is characterized by its rich, dark colour and distinctive grain. The wood is strong, yet workable and has traditionally been used for making fine furniture and gunstocks. The nuts have a characteristically strong flavour, and are used as ingredients in baking and ice-cream. The shells have many commercial uses as abrasives, fillers, and filters in products such as paints, explosives, oil well slurry, cosmetics and dental cleaners.

Table 13.1 Ontario nut varieties.

Moderately hardy species:	
Heartnut (<i>Juglans ailantifolia</i>)	Adapted to wide variety of soil types, grow straight with good wood for timber.
Carpathian walnut, a strain of Persian walnut, (<i>Juglans regia</i>)	These require 150 freeze free day growing season and 2900 CHU (corn heat units), and prefer fertile, well drained loam orchard soils.
Chinese chestnut (<i>Castanea mollissima</i>)	Most recommended cultivars contain Chinese germ plasm resistant to chestnut blight. They prefer acidic, coarse textured, sandy soils.
Hazel-filbert hybrids (<i>Corylus spp.</i>)	Filberts prefer orchard soils, and should be planted in rows running north/south for maximum light interception.
Other species that are not as hardy:	
Hardy almonds, related to peaches (<i>Prunus amygdalus</i>)	Almonds are the least hardy of the northern varieties.
Northern pecans (<i>Carya illinoensis</i>)	Pecans require 3000 CHU, but are adapted to a wide range of soils. Cultivars vary in requirements for growing season length.
Sweet chestnuts (<i>Castanea spp.</i>)	Recommended cultivars are resistant to blight.
Native species already used for their nuts and timber:	
Black walnut (<i>Juglans nigra</i>)	Walnut prefers high quality well drained sites.
Butternut (<i>Juglans cinerea</i>)	Butternut is often called white walnut because of its light coloured wood.
Shagbark hickory (<i>Carya ovata</i>)	This hickory requires moist soils and is found throughout the deciduous forest region.

Marketable quantities of timber can be grown in a small area. A saleable volume can consist of one truckload, or occasionally one tree, depending on quality, location and accessibility. Trees can be planted in small awkward corners of fields or on slopes in a field which are unsuitable for cultivation. Black walnut requires deep, fertile, well drained soils. It can be planted in mixed stands along with conifers and hardwoods such as white ash, red oak or sugar maple. Trees should be planted at least 3.5 m (11 ft) apart. Weed control during the establishment of a plantation results in superior growth and wood quality. The trees should be pruned until the bole is at least 5 m (17 ft) high. Dead branches and no more than one third of the live branches should be pruned in one year.

Juglone

Black walnut and some related species produce a chemical called **juglone** which is known to be allelopathic to many broadleaves, that is, it inhibits those plants growing in its vicinity (Piedrahita, 1984). For example, the growth and survival of tomatoes, raspberries, and most legumes is reduced when grown near black walnut trees.

Research in southwestern Ontario on the Brant-Tuscola-Colwood catena (series) of fine sandy loam soils has found that juglone persists longer in soils which remain wet for long periods of time than in those which are drier (Fisher, 1978). For this reason, tobacco land may be ideal for intercropping with black walnut. In any case, despite juglone, certain forage and field crops can be grown under the trees until the timber is mature and ready to cut. The choice of crops need not be restricted for the first ten years of interplanting because of the small size of the trees. After the trees are five to eight inches in diameter, the crop selection may be limited to certain grasses and grains which are tolerant of high juglone concentrations. In the later stages of a rotation, an intercropped field can also be used for grazing livestock.

PLANTATION ESTABLISHMENT

Establishing nut plantations is similar to establishing fruit orchards. Both demand fairly intensive management initially, although fruit trees require more spraying and pruning than nut trees. Most recommended cultivars will start producing nuts in as little as 3 or 4 years from planting. A mature, fully bearing orchard may take 10 or 12 years from the time of planting. Nut culture is limited by low winter temperatures, short growing seasons and late spring frost. Drought, short growing season, late spring frost, early fall frost, or lack of summer heat can all result in low nut yields or poorly formed kernels.

Another potential reason for poor production is lack of pollination. Japanese walnut and butternut are the only nut species that do not require cross-pollination. Nut trees are often self-infertile and require pollen from another variety for fertilization. Planting more than one variety will avoid such problems. All of the *Juglans* family will cross-pollinate.

HARVESTING AND MARKETING

Nuts are harvested by picking them off the ground soon after they fall. Nut growers will have to be prepared to handle the crop mechanically when acreages justify that type of capital investment. Some nuts fall free from their outer fleshy husk at maturity, while others must have this husk removed in a process called **hulling**. This can be done manually, or mechanically by tumbling them in a cement mixer with fist size stones and water. Many other types of equipment have been designed to hull nuts; commercial equipment is available from the U.S. for large operations.

Once husks are removed, the nuts are dried and stored in a cold place. How, and to what extent the nuts are dried depends on the species. Most nuts are dried on a screen with forced air. Chestnuts are not dried. Instead, they are cured in a process that allows starches to change to sugar, which enhances the flavour. This curing is done in a few days at about 10 to 15°C (50-60°F), with good ventilation and high humidity. Chestnuts are then stored at near freezing temperatures in moist peat moss or sawdust. Nuts mould if they are not dried and stored properly. Cold storage is necessary for dried nuts, because their fat content will cause them to go rancid at room temperature after about a year.

Storing nuts for long periods should be avoided, since from a marketing perspective, the advantage of Ontario grown nuts is their freshness. Cooperatives or joint venture marketing may be necessary to develop a certain volume of supply, if larger market penetration is going to be a possibility. Farmers markets, health food stores, the farm gate and pick-your-own systems are some of the best options for selling Ontario grown nuts. As with all Ontario horticulture crops, smart marketing will be the key to success.

NUTS AND AGROFORESTRY

Nut trees lend themselves well to concepts of agroforestry and permaculture. They can be grown in a sod mulch system or under a sod herbicide method of culture, which involves little or no tillage on a yearly basis. Because of this, soils are not prone to erosion while the land is cropped. For example, in a black walnut intercrop system, crops grown between the rows of trees provide income until the trees begin to produce nuts. The nuts then provide income until the trees are cut for timber.

Other options are available to landowners who are not interested in growing nuts commercially, but would like to grow some for their own use. Many nut species can be incorporated into fence rows, riparian zones, or as carefully placed shade trees. Location is important since nut trees tend to drop debris which is not welcome in many landscape situations.

MAPLE SYRUP ORCHARDS

Maple syrup production is an agroforestry system unique to northeastern North America. Only here do the weather conditions and tree species combine to yield quality sap that is the basis of a very old tradition. Canada supplies about 60% (Quebec 92.5%, Ont. 6%, Nova Scotia 1% and New Brunswick .5%) of world production, while the U.S. supplies the remaining 40% (Buth, 1988). Currently less than 10% of Ontario's tappable trees are used for syrup production, and 2/3 of the syrup consumed is imported from Quebec. The economics of the industry is one reason for this. However, with good planning maple syrup production can offer an alternative source of income during the early spring, when other farming demands are traditionally at a lull.

Maple syrup is produced from the sap of maple trees. Producers want the highest possible volume of the sweetest possible sap to maximize production. Some of the factors which affect flow rate and sugar content of the sap include tree species, tree health, climatic conditions, genetics, total leaf area, and tapping technique. Sugar maple (*Acer saccharum*) and black maple (*Acer nigrum*) are the best syrup producers because of their high yield of sweet sap. Other trees such as red maple (*Acer rubrum*) and silver maple (*Acer saccharinum*) can also be tapped; however, they are less productive.

The concept of growing maple trees for maple syrup production in orchards on marginal farm land is based on high productivity per tap, and improved soil conservation and site protection relative to cultivation. Trees planted at wide spacing may be intercropped with other crops. Several maple orchards have been planted in Eastern Ontario, including one at the Kemptville Agriculture College (Fig. 13.4). Maple producers know that open grown trees grow more quickly, have larger crowns, and are often more productive for maple syrup production than trees growing naturally in an unmanaged sugar bush.

In setting out a maple orchard, maple seedlings or saplings are planted at wide spacing, usually from 6 to 12 m (20 to 40 ft) apart, both within and between rows. At the closer spacing trees will be thinned to ultimately produce a spacing between trees of about 12 m (40 ft). Defective and less sweet trees will be removed in thinnings, thus increasing the average sugar content of the sap produced in the orchard. Either seedlings or saplings may be transplanted. Trees larger than 2.5 cm (1 ") in diameter at



Figure 13.4 Maple plantation established at Kemptville College of Agriculture and Technology. (Courtesy of OMNR)

breast height may be planted, but it is not recommended since it is very labour intensive and more costly to transplant larger stock.

Planting using saplings.

1. Either sugar or black maple are recommended for maple syrup production.
2. Select fast growing saplings secured from openings in the woodlot or it's edge.
3. Prune back the crown of each sapling by about one third.
4. Control grass and weeds around the sapling for 3 to 5 years after planting.
5. Water transplants when planting and during periods of drought.
6. Plant on rich, well drained sites for best results.

Benefits of a maple orchard over a maple woodlot.

1. Sapling maples on good sites should be tappable in about 20 years.
2. Tapholes in fast growing orchard trees will close the summer after tapping, which reduces the possibility of disease entry.
3. Trees will be strong structurally, if properly selected and pruned.
4. Orchards can be ideal for using tubing and vacuum systems, if laid out properly.
5. Trees may be expected to live longer and be healthier.
6. Production of maple syrup will be high, which will result in increased profits.
7. When maples are planted at wide spacing, an intercrop may be produced between them for several years following planting.

PROCESS OF MAKING SYRUP

Tapping, the process of putting a hole in the tree to collect the sap, occurs between late February and mid-March. When temperatures drop below freezing at night and go well above freezing during the day sap begins to flow up from the roots through the sapwood. Trees with a diameter at breast height (d.b.h.) of at least 25 cm can be tapped. For every 13 cm increase in diameter an additional tap may be added to a maximum of 4 taps per tree (Coons, 1987) (Table 13.2). The sap is collected either in buckets or with tubing that drain the sap into storage tanks (Fig. 13.5, 13.6).

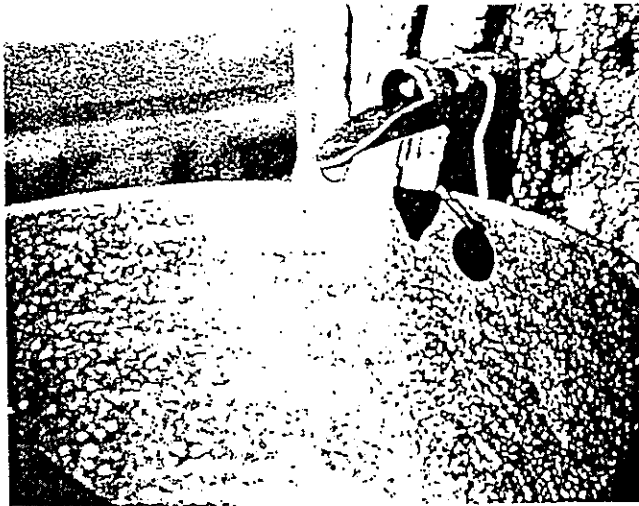


Figure 13.5 Spile and bucket method of tapping. (Courtesy of OMNR).

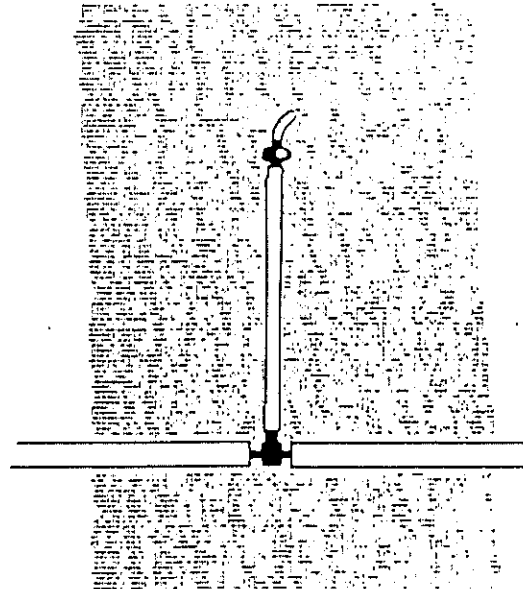


Figure 13.6 Tubing method of tapping.

Table 13.2 Tapholes per tree

Diameter of Tree Bark 1.4 Meters	Measured Outside (4.5') Above Ground	Number of Tapholes per Tree
< 25 cm	< 10"	0
25 - 36 cm	10" - 14"	1
37 - 48 cm	15" - 19"	2
49 - 61 cm	20" - 24"	3
62 > cm	25 >	4

The sap is boiled soon after it is collected to prevent spoilage. Sap is about 97.5% water. Syrup is 34% water. Removal of water and the chemical changes associated with the heat used to do it are the only differences between sap and syrup. It takes roughly 40 litres of sap to produce 1 litre of syrup. Methods of boiling down sap range from a simple pot-on-a-camp-stove to expensive and elaborate reverse osmosis equipment. By far the most common method of processing sap is some variation of the traditional flu pan evaporator. This type of evaporator commonly uses wood for fuel, but can be adapted to use oil, gas, propane, or electricity. Temperature must be regulated, since evaporation that is too slow will yield dark, strong flavoured syrup that is not as valuable as lighter table syrup.

Temperature is often used to indicate when the syrup stage has been reached. Sap is syrup when it boils at 4.06°C (7.3°F) above the boiling point of water. Once the syrup reaches the correct sugar content it is filtered through a clean felt filter and canned or bottled. Filtering is necessary to remove the sediment known as sugar sand. This sediment is concentrated minerals, representing .1% of the sap. If the syrup is to be sold, it must be bottled in clean containers, at 88°C (180°F) or more to minimize the chance of spoilage. These bottles must be labelled and the syrup graded according to the Farm Products Sales and Grades Act.

The syrup can also be boiled down further to make maple butter, maple taffy and maple sugar candy. Maple syrup itself is very versatile and can be used as a sweetener in almost anything. Maple cookbooks provide recipes for meats, vegetables, desserts and many varieties of candy. Many maple producers sell their syrup at the farm gate or a pancake house/ restaurant which specializes in meals prepared with maple syrup. Once again, marketing plays a key role in the economic success of non-timber forest products.

MIXED SPECIES PLANTATIONS²

Trees may be planted either in pure plantations or in mixtures with other hardwoods or conifers. Each procedure has advantages and disadvantages. In their natural environment, hardwood species usually grow in association with other hardwoods or conifers. Plantations of mixed species approximate this natural state. Thus, a mixture of species is appropriate, if the objective of planting is to promote wildlife habitat or naturalization of an area. The greatest advantage of mixed plantations is that they avoid a monoculture, which is a large area planted to one species. Monocultures may be more susceptible to devastating attacks by host specific insects or diseases.

Pure plantations of a single species usually yield the largest number of trees of the most desirable species per unit area. This ensures sufficient trees are available for the selection of the best crop trees in a fully stocked stand at rotation age. Therefore, in plantations of black walnut or other valuable species, pure plantations may produce the highest stumpage value. Dealing with a single species simplifies management, since all of the trees can be treated the same. In mixed plantations allowances must be made for species having different tolerances to herbicides, requiring different pruning, maturing at different times, and having different thinning needs. For these reasons planting mixtures of fruit trees is not recommended without careful consideration.

Planting either a single species or a mixture of several species may not be suitable for all sites. The choice and number of species planted depends on site conditions, management objectives, stock availability, and plantation economics.

² Adapted from: von Althen, F.W. 1990. Hardwood planting on abandoned farmland in southern Ontario. Forestry Canada, Ontario Region, P.O. Box 490. Sault Ste. Marie, Ontario. 77 p.

On intensively managed, highly productive sites, it is generally most economical to plant only the most valuable species. Such plantations may best be compared with fruit or nut orchards. Situations where planting a mixture of trees is recommended include the following:

1. Sites where intensive management cannot be guaranteed.
2. Less productive sites.
3. Plantings for purposes other than high-quality timber/fruit production.

Species must have compatible growth rates and be suited to the site to simplify thinning and pruning procedures. For soil improvement or erosion-control plantings, any species may be selected as long as its growing requirements match site conditions.

NURSE CROPS

Hardwood plantations are notoriously difficult to establish, and often suffer high mortality. They do not compete well with grass and weeds, nor thrive as saplings in exposed conditions. In nature, tolerant hardwoods are usually late successional species, which means they will come in under other trees. Foresters sometimes simulate this by planting a conifer plantation first and under-planting it with the desired hardwoods. Conifers are readily established and act as a nurse crop for the hardwoods. The interplanted conifers are expected to have several effects:

1. Shade out the herbaceous vegetation, thereby increasing the available soil moisture and nutrients, and minimizing need for alternate weed control.
2. Deprive mice and voles of food and cover, thereby reducing girdling.
3. Shelter hardwoods from damaging wind.
4. Encourage hardwood height growth and shade out their lower branches thereby improving stem form.
5. Provide some income while waiting for the hardwoods to mature.

Deer and rabbits may tend to utilize the conifer cover and browse on the hardwood seedlings. Therefore, the success of this method depends on relatively low deer and rabbit populations, and the maintenance of effective weed control around seedlings until the conifers are large enough to provide natural weed control. How soon the hardwoods shade out the conifers depends on how many years head start the conifers have, and what species of conifer is used. Jack pine are very shade intolerant and die out quickly after the hardwoods over take them. This conveniently thins the new hardwood stand. White pine is not as intolerant and will live long enough to produce timber. Hardwoods will also seed in naturally under conifers, provided there is an available seed

source. Under these circumstances, thinning of the conifers is recommended to encourage the growth of hardwoods.

A slight variation of this may utilize some sites more efficiently. For example, Christmas trees may be planted alternately at close spacing with hardwoods. The hardwoods benefit from the shelter, and tend to develop better stem form. Later, harvesting the Christmas trees will thin the hardwoods, increasing their growth rates. The hardwoods will not likely shade out the conifers before they are harvested in 7 to 10 years, especially if the conifers are planted a couple of years ahead of the hardwoods. Such systems are subject to rodent problems.

PLANTING LAYOUT

Species mixtures may be planted in a variety of arrangements, but the simplest and most common arrangement is the planting of alternate rows of two or three species. This simplifies management because trees within rows may be treated the same. Removing less valuable species to provide additional growing space for preferred species is a matter of removing rows. Alternate rows of different hardwood species have proven useful where one species provides shelter or improves the site for another species in the next row. For example, interplanting of black locust (*Robinia pseudoacacia* L.), European alder (*Alnus glutinosa* L.) [Gaertn.] or autumn olive (*Elaeagnus umbellata* Thunb.) has increased walnut growth by providing additional soil nitrogen, competition control, and protection from damage by wind. Planting of silver maple (*Acer saccharinum*) in alternate rows with black walnut has increased walnut growth by providing natural competition control and protection from wind. It also forces walnut height growth.

GROUP PLANTINGS

The chances of survival and adequate growth are greater for trees planted in groups than for individuals scattered throughout the plantation. Planting groups of 4 to 12 trees of one species among a large number of trees of another species may prove more successful and easier to manage than scattering individuals of the first species throughout the plantation.

A variation of group planting is the planting of trees in blocks. The blocks of different species are generally planted in a checkerboard pattern with 5 to 10 rows of 10 to 20 trees each. Smaller or larger blocks may be planted, but very small or very large blocks defeat the purpose of this method of mixed planting. Very small blocks behave like single trees, and very large blocks behave like monocultures.

Planting completely random mixtures of species is suitable on medium-quality sites and in the establishment of wildlife habitats. Completely random mixtures are obtained by opening one bundle of seedlings of each species and mixing all seedlings. The seedlings are then planted as they occur in the mixture. To increase the number of trees of the most valuable tree species within a random mixture, increase the percentage of seedlings of the desirable tree species in the mixture.

The greatest disadvantage of random species mixtures is the limitation in the application of chemical weed control treatments. Because each species has its own level of tolerance to a specific herbicide, the maximum dosage that may be applied safely is that tolerated by the species with the lowest tolerance level. On sites with intense weed competition this dosage may prove insufficient to control weed growth.

Many variations of mixed plantings are possible. The landowner must decide which mixture will most suit a particular property based on management objectives, site conditions, and stock availability. Management objectives must include not only what the landowner wants out of the planting, but also what they are willing to put into it in terms of time and resources.

AGROFORESTRY SPECIALTY CROPS

Agroforestry offers many opportunities to diversify income through specialty crops. A wide variety of herbs can be grown and harvested under trees. Leeks (*Allium tricoccum*), ginseng (*Panax quinquefolium*), golden seal (*Hydrastis canadensis*), wild garlic (*A. canadense*), ginger (*Asarum*), fiddleheads (Ostrich fern, *Matteuccia struthiopteris* var *pennsylvanica*), and wintergreen (*Gaultheria*) are just a few of the species for which small regional markets are already established. Gourmet restaurants and health food stores are frequently interested in getting such products fresh. Farmers markets offer another marketing opportunity for specialty crops.

Shiitake (pronounced shee-tah-kee) mushrooms, (*Lentinula edodes*) are another example of a woodlot specialty crop. They are high in protein, vitamins and essential amino acids, which contribute to their high market potential in the gourmet food and pharmaceutical industries (Hill, 1991). Shiitake are of particular interest because they grow on low grade, small diameter (10-20 cm, 4-8 inch) hardwood logs that result from non-commercial thinnings and improvement cuts (Bratkovich, 1991). Often landowners are reluctant to carry out such woodlot management because of the long wait for economic returns. The short-term cash flow from shiitake production could be enough incentive to overcome this reluctance.

Many trees also offer specialty crop potential. For example, cedar boughs cut and stored properly in the fall can be sold to florists, particularly around Christmas. A volatile oil distilled from cedar foliage is used in perfumes and insecticides. White pine pions, which are the nuts from pinecones, are eaten as nuts. White pine needles and young cones can be ground and used as flavouring. Another possibility is the nectar from certain trees which is valuable to honey producers (Larson, 1990).

These are just a few options for mixing woodlands with food or medicinal crops, which may allow forest landowners to obtain sustainable economic benefit from their woodlands. Whether such specialty crops can be part of an economically viable system depends on location, marketing and landowner creativity.

REVIEW

1. Conifers are much easier to establish than hardwoods and are therefore most commonly used in afforestation.
2. Factors to consider before establishing a Christmas tree plantation include which species to plant, distance from market, layout, water availability, plantation size and marketing.
3. Christmas tree plantations can be a profitable and sensible land use. Only through professional management can top quality trees be produced.
4. Fruit orchards, when combined with another form of agriculture, become important agroforestry systems.
5. Compared to fruit trees, nut trees require less pruning and less spraying. Also, nuts are not as delicate as most fruits and can be harvested by mechanical shaking.
6. Several varieties of nuts are hardy enough to withstand southern Ontario winters. These include heartnut, Carpathian walnut, Persian walnut, Chinese chestnut, hazel-filberts, hardy almonds, northern pecans, and sweet chestnuts. Native nut trees that produce edible nuts include black walnut, butternut, shagbark hickory, and American chestnut.
7. American chestnut is no longer common due to chestnut blight.
8. Maple orchards may be established at relatively wide spacings to encourage large deep crowns necessary for sap production.
9. Mixed plantations are desirable when trying to establish a natural appearing wooded area. They also avoid potential problems associated with monocultures.
10. Agroforestry offers many opportunities for the development of specialty crops. Some possibilities are ginseng, golden seal, wild garlic, ginger, fiddleheads, wintergreen, leeks, and Shiitake mushrooms.

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Chapter 14

TREES AND THE URBAN ENVIRONMENT

Peter Williams

Construction within or near a stand of trees will almost always impact growing conditions either directly or indirectly. Trees are put under stress when site conditions are altered. Sometimes these changes are enough to cause trees to die, but more often they initiate other changes in the stand until some new equilibrium is reached. Over time some trees will become weaker, some trees will become more vigorous, and some new species will invade the stand.

How much a stand is affected depends on site characteristics and the degree, timing and type of changes. For example, one truck driving past a tree once will not likely cause significant compaction damage to tree roots; whereas multiple trips may cause substantial root damage. Some characteristics, such as soil texture, may make a site more sensitive to one type of change than another. This means that the same change on two different sites could have different impacts on the surrounding trees. For example, compaction is often more of a problem on clay soils than sandy soils. If stand health is to be maintained, consideration must be given to how construction will impact the site.

Stand characteristics also determine how much of an impact construction will have on a forest. Younger and more vigorous trees are better able to withstand site changes than older and less vigorous ones. Trees that are already stressed (ex. disease, insect, drought, or heavy frost damage) may not withstand further stress associated with construction. Dieback and windthrow can result from opening a dense stand of trees. Trees that are used to the protection of surrounding trees may not survive suddenly being in the open of a suburban backyard. These problems can be minimized through gradually opening the stand by thinning a few years ahead of construction. Trees not likely to survive development impacts can be removed during the thinning. Stand composition must also be considered during this process, since species vary greatly in their ability to adapt to changes in site conditions. For example, white spruce and red oak are very sensitive to root disturbance, while young sugar maple is fairly tolerant of such damage.

CHANGES DURING THE RURAL-URBAN TRANSITION

Excavation can sever roots, alter drainage patterns, change understorey vegetation and alter (usually remove) topsoil, organic matter, and nutrient balances. On some sites, drainage patterns are significantly altered well beyond the immediate site of the excavation.

Filling around trees can compact the soil around tree roots, change the soil surface and/or bury trees. Unlike the bark of tree trunks, the outer layer of roots is designed to resist rot associated with soil moisture. Thus, soil piled around a tree during filling may ultimately kill the tree. Drainage patterns and other hydrological relations may also be affected by filling.

Sometimes concrete, asphalt and other rubble is used as fill around large development sites. This type of fill does not provide a suitable rooting zone for trees. If trees are to be planted after completion of the project a thick layer of more suitable material must cover this fill and allowances be made for the associated drainage pattern.

Compaction is caused from either heavy machinery during construction and from high volumes of vehicle and foot traffic after construction is complete. Fine roots may be crushed, but just as important is the reduced soil porosity. Fewer and smaller spaces between soil particles means reduced aeration and restricted water movement. Since water percolation through the soil is slowed, more runoff occurs and erosion is accelerated.

Exposure changes can lead to sunscald, windthrow and changes in microclimate. When a dense stand is drastically thinned, the remaining trees must adapt to the new, harsher environment, without protection from neighbouring trees. Temperature extremes are greater and fluctuate more, and trees are exposed to greater wind velocities. Increased light, altered moisture conditions and microclimate changes create new understorey conditions and new competition. Removing a forest edge can have this type of impact, since it is this vegetation is dense from top to bottom.

Hydrology/moisture relations may change substantially with changes in aspect, soil type, compaction, and ground cover (asphalt, grass, etc.). Water movement may be impeded, enhanced, or just rerouted. Internal soil drainage may be altered to create droughtiness or inundation. Often the moisture holding capacity and infiltration rate of the soil are reduced. Instead of rain water soaking into the soil, it flows across asphalt into storm drains, and does not become available to trees. This does not become a problem as long as allowances are made for other water sources at the design stage.

Mechanical injury to stem and branches can affect nutrient transport, disease entry, appearance and structural integrity. This can occur during construction or after the project is complete. Carving, vandalism, lawnmowers, collisions, clotheslines, signs, pet chains, bicycle locks, and swings may all cause mechanical injury to trees after construction is complete.

Chemical stresses affecting urban trees include air and water pollution, road salt, fertilizer (too much or too little), and pesticides.

If a natural woodlot is to become an natural wooded urban park, consideration must be given to compaction from hikers, vandalism and liability issues. If a woodlot is to be thinned to the point of becoming single trees in backyards, exposure becomes a problem (see above). In general, urban trees are under greater stress than rural trees due to the impacts listed above and pollution factors. The high stress can make them more susceptible to insects and diseases.

PARTIES IN A DEVELOPMENT

Developing a piece of property for a residential subdivision or golf course is not a simple matter. There are a multitude of parties involved with varied skills and responsibilities. It is an extremely time-consuming and expensive process, however a great deal of money can be made so there also tends to be a great deal of pressure for development.

This is by no means a complete list of participants in the development process and the various participants will vary with each development and in each municipality. To make the whole process more confusing, a party may take on more than one role. For example, the developer can just liaise between the owner and the other consultants or can perform the function of the planning firm, engineering firm or any others. Environmental consultants may not participate because the expertise may be contained in-house (in the engineering firm), they may not be perceived to be important by the developer, there may be no sensitive issues in the area to be developed, or the municipality may have no stringent requirements for environmental assessment.

Different municipalities will have more or less stringent requirements of a developer, generally if the real estate is more expensive in an area there are more requirements.

Proponents

Landowner
Developer
Planning firm
Surveyors
Engineering firm
Landscape Architect
Environmental Consultant

Contractors

Site engineer
General contractor
Grading contractor
Tree-clearing contractor
Landscape
Builder

Relevant Policy and Legislation

Planning Act
Conservation Authorities Act
Trees Act
Municipal Tree Cutting By-laws
Municipal Zoning and Planning
Parks and Recreation Policy

Regulatory Agencies

Municipal Planning Office
Municipal Engineering Office
City Council
Regional Offices
Conservation Authority
O.M.A.F. - Agricultural land
O.M.N.R. - wetlands, forests
Municipal Parks and Recreation

Other Parties

Neighbours (individuals)
Citizens groups (neighbours
assoc.'s)
Naturalist groups
Other Committees (Waterloo
E.A.C.)

Hazardlands Policy
Municipal Act
Foodlands Ontario
Wetlands Preservation Policy
Woodlot Development Policy

GLOSSARY

Abiotic Referring to the absence of living organisms or non-living factors like climate or soil.

Aeolian Of the wind, refers to sediment deposited through the action of wind.

Afforestation Establishment of a forest or stand in an area not previously forested.

Age Class (Cohort) A distinct aggregation of trees originating from a single natural disturbance or regeneration cutting.

Agrisilvipasture (agrosilvopasture) The production of crops, pasture, livestock and trees on the same piece of land either at the same time or sequentially.

Agroforestry (agriforestry)

- (a) The deliberate integration, in space or time, of woody perennials with herbaceous crops and/or animals on the same land management unit. The concept of an agroforestry system implies ecological and/or economic interactions among the components of the system (ICRAF 1989).
- (b) All of the uses of trees on or associated with farms, not including horticultural monocrops.

Agronomy The application of scientific principles to the cultivation of land.

Allelopathy The harmful effect of one plant or microorganism on another owing to the release of secondary metabolic products (chemicals) into the environment (e.g., juglone).

Alley cropping An intercropping method in which closely-spaced rows of trees are encouraged to coppice to form hedgerows between which crops are grown.

Alluvial Sedimentary material deposited by moving water. Alluvial deposits are usually composed of stratified sand, gravel and/or silt.

Alternate Referring to bud or leaf arrangement in which there is one bud or leaf at a node. Compared to opposite leaf arrangement.

Angiosperms Flowering plants. A group of plants whose seeds are born within a mature ovary, includes broadleaved species (hardwoods).

Annual plant A plant that completes its life cycle within one growing season and then dies.

Annual ring The ring formed in the xylem each year by the contrast of the spring wood and summer wood (also called early and late wood); seen in trunk cross sections in both the heartwood and the sapwood.

Apical meristem An area of active meristematic cells (actively dividing cells) at the very tip of a shoot or root.

Artificial Regeneration (reproduction) Creation of a new age class by renewal of a tree crop by direct seeding, or by planting seedlings or cuttings.

Aspect The compass direction towards which a slope (downward) faces (0 to 360 degrees from north).

***Bacillus thuringiensis* (B.t.)** A non-chemical, biological insecticide. The Bt used in Canada kills *Lepidoptera* larvae when ingested. It is used to control epidemics of spruce budworm, gypsy moths, forest tent caterpillar.

Balled stock Young trees which have been dug up with the root ball (roots plus adjacent soil) intact and wrapped in burlap.

Bare root stock Seedlings which are shipped from the nursery without soil on the root system.

Basal area

- (a) Of a tree: the cross-sectional area (in square meters) of a trunk at breast height (1.3 m above the ground). For example, the basal area of a tree 40cm in diameter is approximately 0.13 m².
- (b) Of a hectare of forest: the sum of basal areas of the individual trees on the hectare. For example, a well stocked hardwood stand might contain 18 to 23 square meters of basal area.

Basal pruning The selective removal of the lower branches of a tree.

Biltmore stick A type of scaling stick which has gradations stamped upon it for estimating tree diameter, height, volume and number of 16-foot logs a tree might yield.

Biomass The total weight of dry matter grown by and attached to an organism.

Biotic Alive or pertaining to life and living organisms.

Bipinnate A leaf that is pinnate for both its primary and secondary divisions, ie., leaflets are attached to both primary and secondary petioles.

Blade The expanded portion of a leaf, sepal, petal or other plant part.

Board foot A unit of measurement of lumber and sawlogs represented by a board 12 inches long, 12 inches wide, and 1 inch thick or the cubic equivalent. In practice, the board foot calculation for lumber 1 inch or more in thickness is based on its nominal thickness and width and the length. Lumber with a nominal thickness of less than 1 inch is calculated as 1 inch. In the lumber industry, the working unit is 1000 board feet, abbreviated Mbd.ft., MBF.

Brix A scale used to measure colloid concentrations in solutions, eg., sugar content in maple sugar.

Broad-leaved trees Those trees that have leaves that are broad compared to their length, are net veined. In Canada, most broadleaves are deciduous (the leaves are shed each fall). Broadleaves are also called hardwoods.

Bud An undeveloped branch, leaf or flower, usually enclosed by protective scales.

Buffer strips An area left to cushion the impact of some sort of disturbance. Examples would be an unharvested buffer strip around a lake in a forested area, a buffer strip left to protect a wetland from urban development or a riparian buffer strip to reduce the impacts of agriculture on a stream.

Butt diameters The diameter measurement taken from the large or lower end of a log.

Calipers An instrument used to measure diameters of trees or logs (a graduated rule with two arms at right angles to the rule, one fixed to one end of the rule and the other sliding parallel to the fixed arm).

Cambium A layer, one or two cells thick, of meristematic tissue between the xylem and phloem (vascular cambium) or between the inner bark and the wood of a tree (cork cambium).

Canker A localized injury in or to the bark or stem of woody plants. Can be caused by a variety of factors including fungus, bacteria, mechanical damage or other injury.

Canopy The continuous cover of branches and foliage formed collectively by the crowns of adjacent trees.

Chlorophyll The green pigment found in the chloroplast of plants, important in the absorption of light energy, and production of sugar during photosynthesis.

Cleaning A release cutting made in the seedling or sapling stage in order to free the favoured trees from less desirable individuals of the same age class which overtop them or are likely to do so.

Clearcutting A commonly used term to describe a harvesting system where most or all of the existing stand of trees are removed. See: silvicultural clearcut and commercial clearcut.

- Climax forest** In plant succession, the final stable forest community that is more or less in equilibrium with its environment and is not likely to be replaced by another community without catastrophic disturbance.
- Colluvial** Pertaining to deposits of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action.
- Colonizers** Immigrant plant species which are the first to become established in a peripherally unsuitable area (not necessarily an ecologically barren area).
- Commercial clearcut** A clearcut conducted to some commercial criteria (e.g., removing all commercially valuable species). Little consideration is made for stand regeneration.
- Competition** The more or less uneven struggle for environmental resources among individuals which require the same resources on the same land area, usually at the same point in time.
- Composition, stand** The proportion of each tree species in a stand expressed as a percentage of either the total number, basal area, or volume of all tree species in the stand.
- Compound leaf** A leaf whose blade is divided into several distinct leaflets.
- Conifers (gymnosperms)** A tree belonging to the order Coniferales, which is usually evergreen. Each seed is borne on a scale of a cone, and has needles, awl, or scale-like leaves, such as pine, spruces, firs, and cedars; commonly referred to as softwoods.
- Container stock** Seedlings prepared for transplanting that have been grown in pots or other containers. Fibrous, plastic or paper pots can be used.
- Coppice** Vegetative or clonal reproduction where new shoots emerge from dormant buds, usually following some form of injury. Stump sprouts, stool shoots and root suckers are types of coppice growth.
- Cord** A unit of measure of stacked round wood. A standard cord occupies 128 cubic feet of space. A "standard cord" is a pile of wood 8'x 4'x 4', consisting of a gross volume of 128 cubic feet. This measure is commonly used for pulpwood measurement. A "face cord" has no real standard and generally refers to a pile 8 feet long, 4 feet high, consisting of pieces 1-2 feet long. This measure is commonly used for firewood measurement.
- Cork cambium** The meristematic tissue between the bark and wood that gives rise to cork cells in the bark.
- Cortex** The primary tissue of a stem or root bounded externally by the epidermis and internally in the stem by the phloem and in the root by the pericycle.

Cruising Examining forestland to determine species and estimate volumes and grades of standing timber.

Cull A tree or log which is rejected because of defects or because it is below required standards.

Cultivar A cultivated variety of plant, produced by human-controlled breeding.

Cut-your-own A type of Christmas tree farm where buyers can choose and cut their own tree.

Cuttings Method of vegetative reproduction where sections of stem are planted that sprout and grow into new plant genetically identical to the parent (source of cutting). Willows and some poplars are commonly reproduced using cuttings.

Dark reactions The synthesis steps in photosynthesis that do not directly require light energy.

DBH (Diameter at breast height) The diameter of a tree trunk at breast height (breast height is at 4.5 ft or 1.38 m above the ground at the uphill side of the tree).

Deciduous Falling off or being shed at the end of the growing season. Usually describing trees that lose their leaves each autumn.

Defoliate The act of stripping leaves from plants.

Dendrology The study of the identification and classification of trees.

Denitrification The process by which NO_3 is converted to N_2 , NO , N_2O and NO_2 under anaerobic conditions.

Dibble A long, narrow, pointed tool for making holes in the soil for planting trees.

Dominant The most numerous and vigorous species in a mixed crop.

Doyle log rule A rule for determining the volumetric content of logs. It is based on a mathematical formula:

$$V = (D-4)^2 \times L / 16 \quad \text{where} \quad V = \text{volume in board feet,} \\ D = \text{DIB at the small end of the log in inches, and} \\ L = \text{length of log in feet}$$

Drumlins Spoon shaped hills of glacial till with smooth convex contours. Generally occur in clusters called drumlin fields. The long axes all point in the same direction which is considered to be the direction of movement of the glacier which formed them.

Dysgenic This use of practices that deteriorate the hereditary qualities of future generations. Example is where the best specimens of a species are selectively removed as in trophy-hunting or high grading.

Glossary

Earlywood Wood formed during the early period of annual growth; usually less dense than wood formed later.

Ecotype A subgroup within a species which is genetically adapted to a unique or specific habitat type.

Energy plantation A plantation with the primary objective of producing wood for energy, either from combustion; to heat buildings, dry grain or produce electricity, or chemically (alcohol). Often involves the growth of fast growing species or hybrids to produce the maximum amount of biomass.

Epidermis A superficial layer of cells occurring on all plant surfaces.

Eskers A knobby, often serpentine ridge of coarse gravel and sand deposited by meltwater in crevasses and tunnels underneath a glacier, generally near the front or at the edge.

Eugenic Practices that improve the hereditary qualities of future generations. (*e.g.* breeding programs and careful and unbiased selection logging)

Even-aged forest A forest in which all of the trees present are essentially the same age.

Evergreens Trees on which the leaves do not die in the same year as they appear.

Exotic trees Trees which are not native to the area in which they are growing.

Fallow period Refers to a period of time in which a field is left to recover from cultivation. It may be cultivated to control weeds but it is not cropped.

Felling The cutting of a standing tree.

Filter strip A strip of trees or plants which filter out contaminants such as excess agricultural fertilizers and sediment before they reach rivers or ground water.

Flushing Part of the life cycle of a plant when the buds break and new leaves appear.

Forest ecosystem All the living and non-living material in an area predominated by trees and other woody species. It includes all the interactions that produce an exchange of materials between the living trees and other organisms and non-living materials.

Forest entomology The study of the effects of insects upon forests, forest products, and the forest environment.

Form The general shape of a tree, including stem and branching characteristics. Trees of good form for timber have straight stems that are more or less cylindrical, have fine branches and do not taper rapidly.

FRI (Forest Resource Inventory) A Ministry of Natural Resources program which inventories the forests and landscape of Ontario using a Geographic Information System (GIS). Aerial photography and ground information are used to map forest stands and keep track of their characteristics.

Furrowing A method of site preparation for tree planting where small trenches, or furrows are dug to accommodate young trees either in the furrow or on top of furrow edges.

Genealogies Records or tables showing the descent of an individual from its ancestors.

Girdling Completely encircling the trunk of a tree with a cut that severs the bark, phloem and vascular cambium preventing the translocation of sugars from the foliage to the roots. The tree will slowly die.

GIS (Geographic Information Systems) A type of information system that uses a spatial data base to keep track of data on geographic areas. Two types of GIS are used; polygon based systems keep track of characteristics of relatively homogeneous polygons or map units and raster-based systems, which keep track of the characteristics of cells in a similar fashion as a television screen.

Glacial lakes A lake dammed by a glacier or formed from glacial meltwater.

Glacial seas Much the same as glacial lakes except the waters were saline.

Glaciolacustrine Soil deposits characterized by relatively deep, well stratified deposits of silt and clay, often alternating in thin layers.

Gley A compact, sticky, bluish- or olive-grey soil horizon formed under conditions of more or less permanent saturation. The colours result principally from the reduction of iron.

Group selection An uneven-aged silvicultural harvesting system where small groups of trees are removed, creating small openings throughout the stand.

Grub hoe A heavy hoe for digging up roots, stumps, etc.

Gymnosperms see conifers

Hardwood A common term used to describe broadleaf, usually deciduous, trees such as oaks, maples, ashes, elms, etc. Not related to wood density.

Heartwood Darker coloured wood in the centre of a tree wood composed of dead, non-functional xylem tissue. The colour is from the deposition of chemicals and particles impregnating or plugging the tissue, making it somewhat resistant to fungus and decay. It does not generally effect the strength or density of the wood.

- Hedgerow** A dense row of bushes, trees, shrubs, etc. planted as a hedge to act as a fence, dividing line, windbreak, wildlife corridor, etc.
- Heeling-in** Placing bundles of trees in trenches and pressing soil firmly around the roots. This serves as a temporary storage site before the seedlings are transplanted.
- Herbicide** A chemical which kills plants.
- High grading** A commercial harvesting practice where the most valuable trees are removed. This includes the removal of the best individuals of one or more species or the selective removal of a species, only considering financial aspects of the operation. See dysgenic.
- Holistic approach** An approach to management where a system is seen as more than just the sum of its parts. In the management of resources this approach takes into account all parts of the ecosystem rather than just concentrating on resources of commercial value.
- Hydrometer** An instrument for determining the specific gravity of liquids.
- Hypsometers** Instruments which use the trigonometric principles of triangles to estimate tree height.
- I.C.R.A.F.** The International Council for Research in Agroforestry. An international agency based in Nairobi, Kenya that is central to the development of agroforestry as a discipline and science. Their activities have been mainly in less-developed countries in the tropics.
- Increment borers** A hollow auger-like instrument used to bore into the trunk of a tree to remove a cylinder of wood about the diameter of a soda straw containing a cross-section of the tree's growth rings.
- Insecticide** A chemical that kills insects.
- Instar** The stage of an insect between moults (shedding of the exoskeleton).
- Integrated Resources Management (IRM)** The deliberate and carefully planned management of a forest area taking into account the values of all resources in the area.
- Intercropping** Involves growing trees and crops together to obtain economic and/or ecologic benefits from the trees as well as the field crop. Intercropping can be used to ease marginal lands out of cash crop production, generate income during the early stages of fruit and nut orchard establishment, and add ecological diversity that will benefit the environment as well as human.

International 1/4 inch log rule A rule for determining the volumetric content of logs. It is based on the mathematical formula:

$$V = 0.199D^2 - 0.642D \quad \text{where}$$

V = volume in board feet for a 4-foot section, and

D = diameter inside bark (DIB), in inches on the small end of a 4-foot length.

Inventory A survey of a forest area to determine such data as area condition, timber volume and species, site quality for planning, purchase, evaluation, management, harvesting or other purpose.

Juglone An allelochemical produced by plants in the *Juglans* genus, (eg., black walnut or butternut) that impedes the growth of many broadleaves and conifers.

Kame Knobby hills of irregularly sorted sand and gravel formed at the edge of a melting glacier, or steep-sided mound of glacial drift formed from melting stationary ice broken off of a glacier.

Knot The type of wood found where a branch grows out from the stem of a tree.

Latewood The denser, smaller-celled, later formed part of an annual growth layer along the trunk and branches of a tree (summerwood).

Lenticels Small breathing pores in the bark of trees and shrubs that permit gas exchange between the plant and the atmosphere.

Light reactions Those reactions in photosynthesis that are driven more or less directly by light energy.

Lobed Referring to leaves which have rounded projections.

Log grades A classification of the quality of log and subsequent products, that may be produced from a given tree.

Loose knot The type of knot formed after a branch dies. This kind of knot will weaken the wood as the branch and the trunk do not grow together. Also called black knots.

Lumber Boards that have been sawn from logs.

Macroclimate The climate of a large geographic region or area.

Macronutrients Elements, such as potassium and nitrogen which are essential in relatively large quantities for proper growth, development and physiology of a plant.

Marginal land rehabilitation Rehabilitation of lands that are no longer, or never were, suitable for the current use. In the case of agriculture, marginal lands may be no longer profitable to farm due to physical degradation caused by erosion, excessive cultivation, changes in the nutrient availability, etc. Trees can be established to rehabilitate lands to improve the site, generally so that it can be productively used. (e.g., for forestry, agriculture or natural areas).

Mattock A tool for digging holes that is shaped like a pick; one end is pointed and the other is flat with sharp edges.

Meristem An area of active cell division in a plant. In a tree, terminal (apical) meristem is located in buds and the growing tips of stems or roots. See cambium.

Micronutrients Chemical elements which are needed in relatively small quantities for the proper growth, development and physiology of a plant.

Monoculture A cultural practice where a single crop species is grown.

Moraine A knobby ridge formed by material being pushed up in front of an advancing glacier, or gravel and sand deposited by meltwater at the edge of glacier.

Mulch Any substance which is spread over the soil to reduce weeds, conserve moisture or protect from frost. Common mulches include straw, leaves, or plastic.

Multiple use Administering forested lands for a number of objectives in the best combination of uses. In practice, a dominant use is given for an area and other objectives managed secondarily.

Node The region of the stem where one or more leaves, buds or branches are attached.

O.M.A.F. Ontario Ministry of Agriculture and Food. OMAF regulates farm produce and activities, and provides agricultural technical advice and assistance.

O.M.N.R. Ontario Ministry of Natural Resources. Their mandate is to manage Ontario's forests, wildlife and mineral resources.

Ontario log rule A rule for determining the volumetric content of logs. It is based upon the mathematical formula:

$$BF = (0.55 D^2 - 1.2 D) \times L/12$$

where BF = board feet;

D = diameter inside bark (in inches at the small end)

L = log length (in feet).

Opposite A term describing leaf or branch arrangement on a stem; adjacent pairs of leaves or branches are positioned directly opposite to one another at the same node.

- Outwash** Sand and gravel deposited in stream terraces or broad fans by fast moving water draining away from a glacier.
- Palmate** Leaves having lobes that radiate from a common point.
- Parenchyma** A tissue of plants, made up of thin-walled cells of similar diameter, (which often function as spongy tissue. (*e.g.* pith or internal parts of leaves.)
- Parent material** The unconsolidated and more or less chemically unweathered mineral or organic matter from which a soil profile is developed by pedogenic processes.
- Patch clearcut** An even- or uneven-aged silvicultural system where patches are clearcut throughout a stand. The size of the patches varies with the forest type, objectives and sizes of the areas being managed. The uneven-aged nature of the forest is maintained when small patches are used.
- Pathogens, primary/secondary** Disease producing agents. Primary pathogens are those that attack a tree directly and cause disease, secondary pathogens are those that will attack a tree which has already been weakened by some other factor.
- Paedogenesis** The mode of origin of a soil, with reference to the processes responsible for the development of the solum, or true soil, from unconsolidated parent material.
- Prescribed Burning** The application of fire, usually under existing stands and under specific conditions of weather and fuel moisture, in order to control vegetation to meet goals of silviculture or hazard reduction
- Perennial** A plant that lives for an indefinite period of more than one growing season.
- Pesticide** A chemical used to kill pests (includes herbicides, insecticides etc).
- Petiolate** Having a petiole; referring to a leaf that is attached to its stem by a petiole.
- Petiole** The stem which supports the blade of a leaf.
- Phloem** Vascular tissue which translocates sugars and other foods from the leaves, or other areas, downward in the branches and stem to the roots. The phloem is located just beneath the bark in a tree stem and develops from the outside layer of the vascular cambium.
- Photogrammetry** The science of making accurate measurements and maps from aerial photographs.
- Photosynthesis** A process in plants by which light energy is converted to chemical energy using carbon dioxide and water, and is stored in the carbon bonds of carbohydrates, mainly sugars which are used as food by the plants.

- Pinnate** A compound leaf arrangement where leaflets branch from a central axis, the primary petiole.
- Pioneering species** Species which are ecologically adapted to colonize a relatively unoccupied site. Generally considered to initiate the cycle of succession. In forest succession, examples of pioneering species would be jack pine and hawthorn which typically colonize a site after catastrophic disturbance such as fire or clear-cutting
- Pith** The spongy, innermost tissue of stems and some roots, composed primarily of parenchyma tissue.
- Plug seedlings** Container grown seedlings which are grown in small, tall and thin plastic tubes. Their roots form a cylinder which makes them easy to plant.
- Porosity** The degree to which the area or volume of an object is unoccupied.
- Pruning** The selective removal of live or dead branches or parts of branches from standing trees.
- Pubescence** A broad term referring to fine, woolly hairs, such as on leaves, twigs or buds.
- Pupation** The process of entering the larval resting stage, the stage between larva and adult in insects with complete metamorphosis.
- Rays** Vertical sheets of parenchyma cells extending along a radius of a stem or root. Oaks have prominent rays in the wood.
- Refoliate** A reflushing of the leaves of a tree which was previously defoliated.
- Reforestation** The establishment of a new forest on a site that previously supported a forest by seeding or planting seedlings.
- Refractometer** An instrument used to measure the index of refraction (bending light rays) of a substance.
- Regeneration** The process of replacing one stand of trees with another either artificially, by planting, or naturally from seedlings or coppice shoots.
- Release cut** The final cut in a shelterwood silvicultural system to remove the remaining residual trees from the original stand to release the established regeneration; OR a heavy thinning to promote growth of the most vigorous trees; OR a cleaning to release desirable species.
- Resin ducts** Tubes or ducts in a woody stem or a leaf, especially in conifers, lined with glandular epithelium which secrete resins.

Riparian buffer strips Trees planted along stream or river banks to protect them from adjacent land uses like agriculture, forestry or urban development.

Rodenticide A chemical used to kill rodents.

Root cap A thick, protective mass of parenchyma cells covering the meristematic tip of the root.

Root collar The junction between the roots and stem of a woody plant, noted by a slight swelling.

Root flare The widened portion at the base of a tree where the roots swell outward from the stem.

Rotation The period of years required to establish and grow timber crops to a specified condition or maturity.

Salvage cut A cut made primarily to remove trees that have been, or are in imminent danger of being killed or damaged by various agents.

Sanitation cut The removal of (1) dead, damaged, diseased, hazardous or susceptible trees or their parts, or (2) other vegetation that serves as alternate host for crop tree pathogens, essentially to prevent or control the spread of pests or pathogens.

Sap The fluid part of a plant which circulates through the vascular system and is composed of water, gases, salts and organic products of metabolism.

Saprophytic A plant that is capable of living upon decaying organic matter.

Sapwood The light-coloured wood which appears on a cross section of a tree trunk, usually it is the most recently formed layers of wood in the outer part of the stem between the heartwood and the bark. It is composed of living xylem tissue and conducts water and nutrients from the roots to the upper parts of the tree.

Scaling Estimating the sound wood content of a log or group of logs in terms of volume, mass, cords or some other marketing unit.

Scaling defects Defects in cut timber that reduce the volume of lumber that can be obtained from a log.

Scaling stick A graduated stick for measuring the diameters and volumetric contents of logs; both measures are stamped on the stick.

Scolytus A genera of bark beetles that feed upon the phloem and adjacent surface of the wood of a number of tree species.

- Sediment** Soil material deposited by water or air (usually refers to water deposits).
- Seedtree cut** Even-aged silvicultural system where most trees are removed from the stand except for a few desirable trees which are left singly or in small groups to provide seed for regeneration.
- Serrated** A term describing a leaf with a notched or toothed edge.
- Shade tolerance** A measure of the ability of a plant to grow and thrive in the shade of other individuals.
- Shearing** Trimming and shaping the crown or canopy of a tree; usually refers to Christmas trees.
- Shelterbelt** A natural or planned barrier of living trees and/or shrubs maintained for the purpose of reducing erosion and/or providing shelter from wind. A shelterbelt is distinguished from a windbreak in that it is usually comprised of multiple rows of trees/shrubs.
- Shelterwood cut** Even-aged silvicultural system where the existing stand is removed in stages to provide environmental conditions to establish regeneration of desirable species. After appropriate regeneration is established the remaining overstory is removed in a release cut.
- Silvicool tarp** A tarpaulin under which seedlings may be stored before they are planted. Its surface reflects heat to prevent heat damage to seedlings.
- Silvics** The life history and general characteristics of forest trees and stands with particular reference to environmental factors as they affect tree selection, growth and reproduction and the growth and development of forest stands.
- Silviculturalist** One who is trained in the art of producing and tending a forest; the application of silvics in the treatment of a forest; the theory and practice of controlling forest establishment, composition and growth.
- Silvicultural clearcut** A even-aged silvicultural system where all trees except those smaller than 2.5 cm in diameter are removed. This method produces an environment for reproduction that is not influenced by the previous stand.
- Silvicultural prescription** A component of management plan for a forested area that gives a prescription for some management intervention or activity. It may include management objectives, the species, number and sizes of trees or wood to be removed, the probable response of the area to the cut, and provisions for regeneration.
- Silviculture** The applied science of reproducing and manipulating a forest in order to fulfil management objectives.

Silvipasture (Silvopasture) Growing pasture and trees together on the same piece of land to gain profit from the production of livestock and wood products.

Simple Made up of one piece, as in a leaf with only a single blade.

Single tree selection An uneven-aged silvicultural system that involves the removal of certain individual trees from the existing stand to provide space for reproduction. This produces a seedling environment that is strongly influenced by the remaining stand, and leads to a stand composed of several age classes.

Site The complex of physical, biological and ecological factors of an area which determines what forest or other plant community it may support.

Site condition The relative ability of a site to produce tree growth (site quality).

Site potential The mean annual increment in merchantable volume which can be expected for a forest area, assuming it is fully stocked by one or more species best adapted to the site, at or near rotation age.

Skidder A vehicle designed for dragging logs out of the forest.

Skidding The process of dragging cut logs from the forest stand to a roadside or landing area where they may be further processed or transported to the mill.

Slit planting A method of tree planting where the roots are inserted in a slit in the soil made by rocking the handle of the shovel back and forth.

Softwood One of the botanical groups of trees that generally have needles or scalelike leaves (conifers); can also refer to the type of wood from coniferous trees.

Soil Finely divided mineral and organic material which is capable of supporting life.

Spile A hollow tube which is placed in the tap hole of tree to drain the sap; used in maple syrup production.

Spillways The abandoned channel of a glacial meltwater stream or river. A spillway will sometimes contain the channel for a smaller, present-day stream.

Spore A small reproductive body produced by mosses, ferns, etc. and capable of giving rise to a new individual.

Staking The use of poles or sticks (stakes) to support a newly planted tree until the root system develops.

Glossary

- Stand** A contiguous group of trees, sufficiently uniform in species composition, arrangement, condition, and age classes to be a distinguishable unit.
- Stand density** A qualitative measure of tree stocking. Most often represented by stem density or basal area, but can also be estimated from biomass, crown closure, volume or weight.
- Stand volume** The volume of wood contained in a standing forest.
- Stewardship** The management of resources, emphasizing continued sustainable productivity.
- Stipule** Small appendages at the base of leaf petioles.
- Stocking** The density of a stand compared with the ideal for best growth and management.
For example: Stand basal area = 10 m²/ha; optimal basal area = 18 m²/ha
therefore, stocking is 10 m²/ha / 18 m²/ha = .56 or 56%.
- Stumpage** The value of standing timber (on the stump). The value of the tree(s) before it is cut and removed from the stand.
- Succession** The progression of plant communities where new species will invade and replace a pre-existing community in a progression from bare soil to a climax or stable community.
- Sustained yield** The yield that a forest can produce perpetually at a given intensity of management; reproduction and growth replace removals; a term commonly applied to timber but can also be used for other resources.
- Swidden cultivation** A rotational agroforestry system where a forested area is cleared and actively cultivated until the soil becomes degraded, whereupon the land is allowed to go back to trees and a new area is cleared and cultivated. Also called slash-and-burn agriculture, forest-fallow or bush-fallow systems.
- Tally sheet** The data sheet upon which counts of trees, tree species, logs, diameters, distances or other forest measurements are recorded.
- Tannin** An astringent vegetable compound which gives some bark its reddish colour and is often used for tanning hides.
- Tap or tap hole** The hole drilled in the stem of a tree from which sap is drained. Can also refer to the process of drilling (tapping) a hole in the stem.
- Taper** The gradual decrease in diameter in a stem of a tree or log from the base to the top.
- Taungya** The practice of using intercropping for the establishment of a forest plantation.
- Thinning** A cutting made to reduce stand density of trees primarily to improve growth, enhance forest health, or to recover potential mortality.

Tight knot The type of knot formed when both the tree and the branch are alive and growing. This kind of knot is fused with the stem and will not weaken the wood. Also called red or sound knots.

Topography A description of the surface features of the landscape.

Tracheid An elongated, thick walled, cell conducting and supporting cell found in the xylem of most vascular plants.

Trichogramma minutum An egg parasite of the spruce budworm and other insect pests. This parasitic wasp deposits its eggs into larval Lepidopterans (caterpillars); their development causes the death of the caterpillar host.

Trifoliate A leaf having three leaflets.

Uneven-aged Applied to a stand of trees in which there is a considerable difference in the age of the trees; composed of several age classes. Typically described by an inverse-j shaped diameter distribution with many small trees and progressively fewer trees in larger size classes.

Variety A subdivision of species having some heritable characteristics distinctly different from the typical.

Vascular cambium The lateral meristem located between xylem and phloem in stems that grow in diameter; its cells divide to produce secondary xylem (wood) on the inside and secondary phloem (part of bark) on the outside.

Venation The system or pattern of veins in the tissues of a leaf.

Veneer A very thin layer of wood that is sliced from a log or peeled on a rotary lathe to a uniform thickness; used as a facing for other woods or to make up the various layers in plywood. Generally made from larger and more valuable logs.

Viable Capable of growth and development.

Wedge planting A method of tree planting. With a shovel or tree spade, a wedge of soil is removed, seedling roots are placed against the flat, upward cut and the wedge is replaced.

Weir An obstruction or dam, built across a river to divert or control the rate of flow or raise the water level.

Whip A branchless shoot of a woody plant, especially one resulting from the first years growth of a bud or graft; or a tree with a narrow crown and thin stem that is flexible and liable to 'whip' in strong winds (whip trees).

Whorled Having leaves or buds arranged in a circle around the node on a plant stem.

Windbreaks Single rows of living trees and shrubs maintained to provide wind protection for crops, soil, roads, livestock and buildings. Less than five rows wide.

Wolf trees Trees occupying more space than its silvicultural value warrants, inhibiting better neighbouring trees. A term usually applied to broad-crowned, short-stemmed trees. These trees can be important as wildlife habitat.

Xylem The portion of the vascular system that consists of tracheal tissue and wood parenchyma. The xylem conducts fluid upward from the roots, through the stem and into the branches and leaves in plants and provides mechanical support.

Zone of elongation A region behind the apical meristem where cells elongate and the measurable growth occurs.

