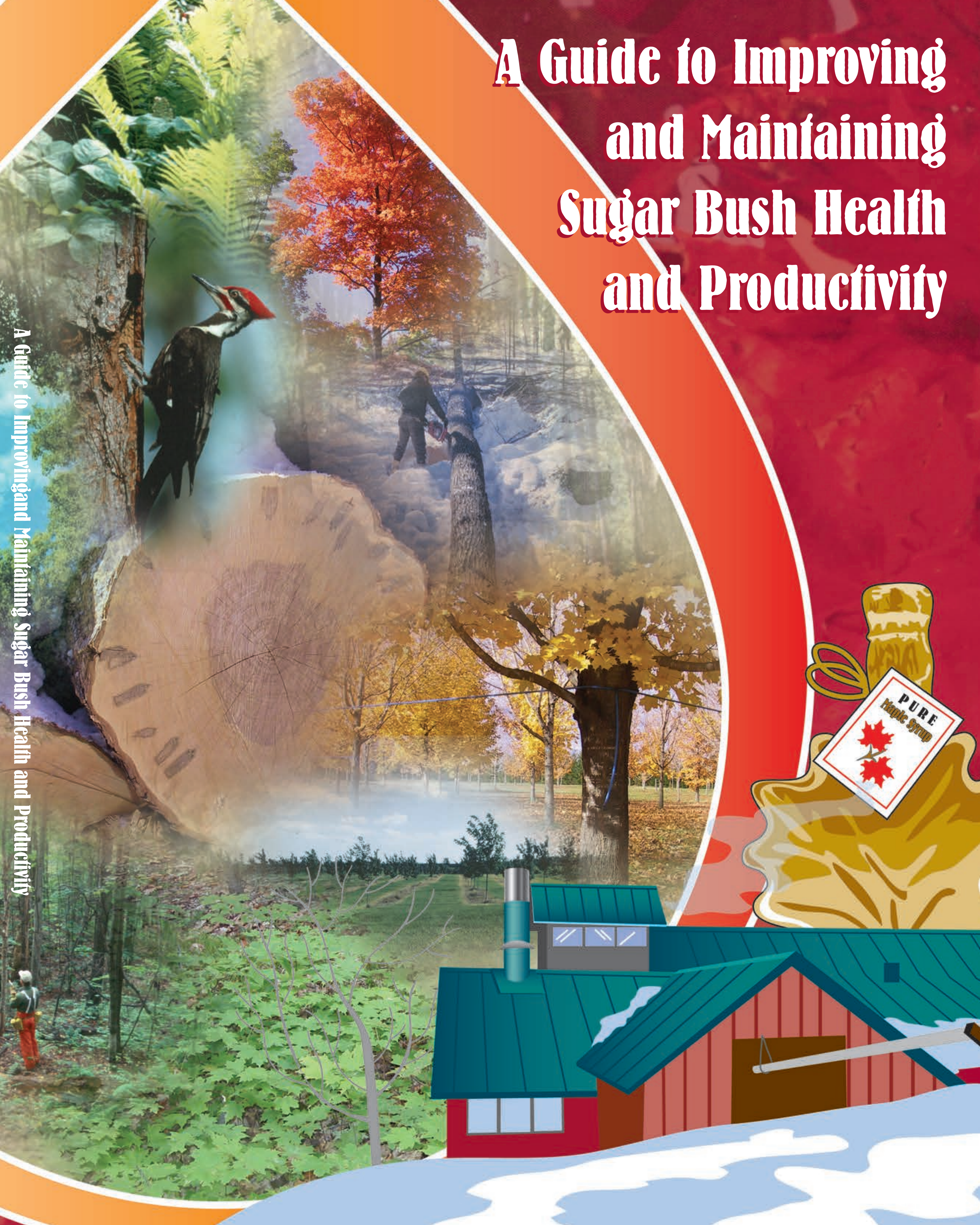
A Guide to Improving and Maintaining Sugar Bush Health and Productivity



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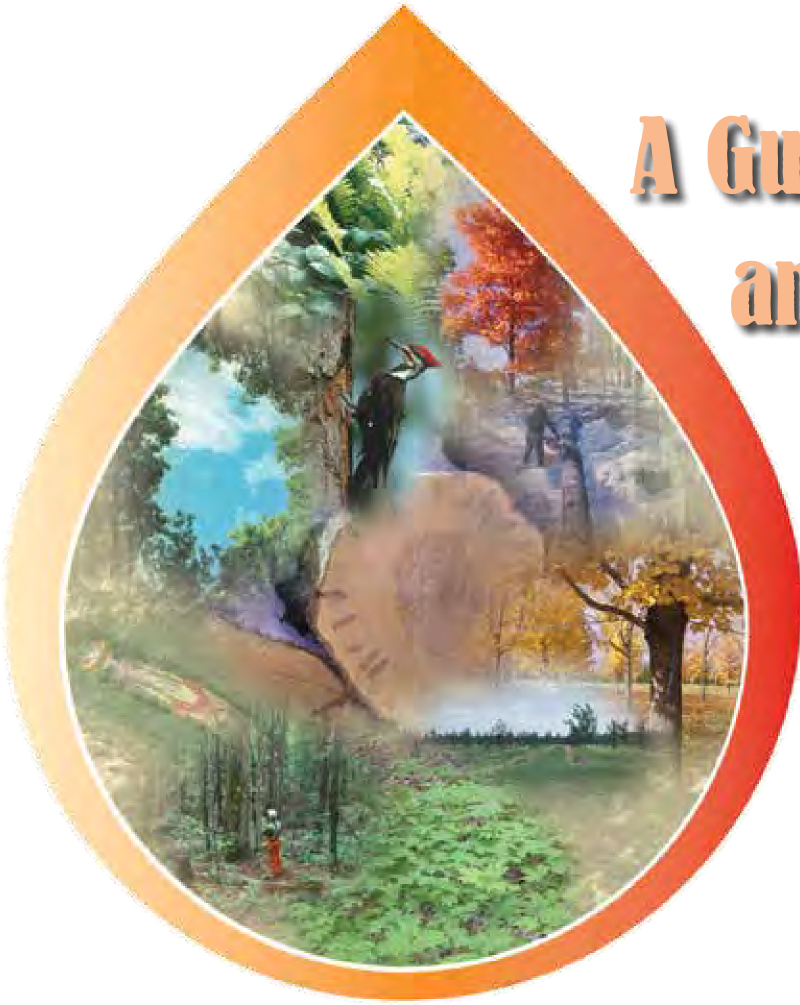

A Guide to Improving and Maintaining Sugar Bush Health and Productivity

2006

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Ontario Maple Syrup Producers Association

Eastern Ontario Model Forest

Ontario Woodlot Association

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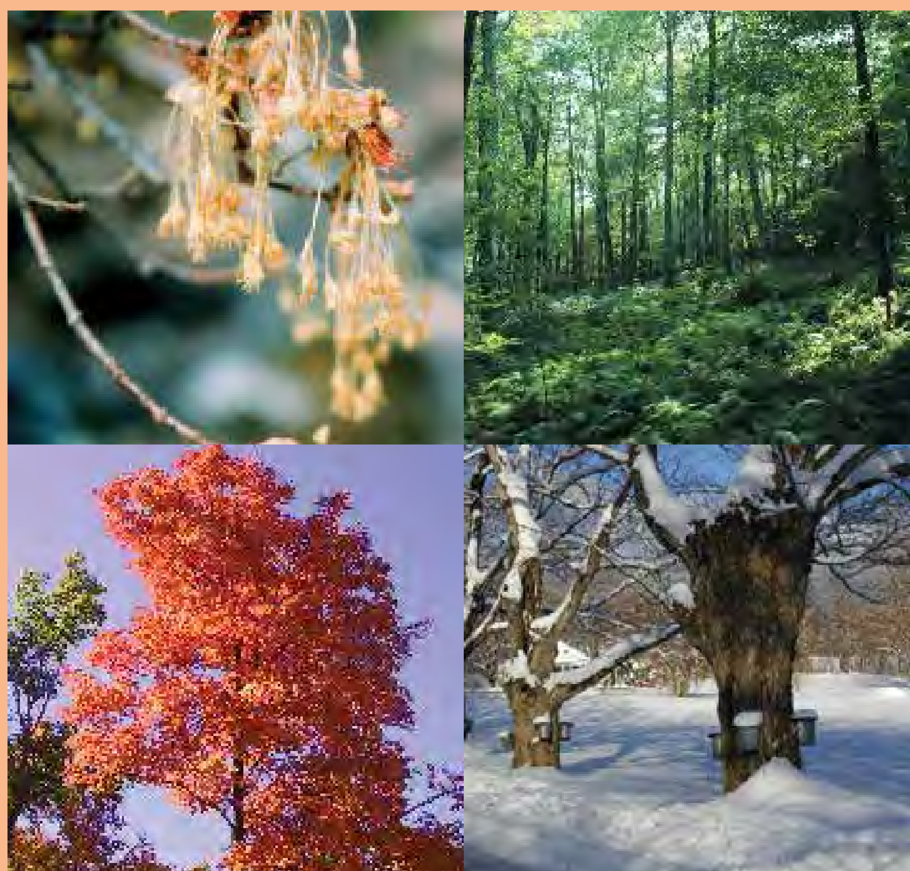
"A healthy and productive sugar bush provides the foundation for a profitable maple syrup production enterprise." – Agroforestry Specialist, Eastern Ontario

"I enjoy working in my sugar bush and observing the rapid growth response of young maple trees." – Maple Producer, Ontario

"I want to leave my sugar bush in a healthier, more productive state so that my children and grandchildren can enjoy the maple tradition as I have." – Maple Producer, Ontario



"I enjoy walking in the sugar bush with my family and observing song birds and other animals in the off-season." – Maple Producer, Ontario

"I had a good cut of veneer logs from my managed sugar bush – some woods operators told me that this was not possible if the trees were tapped." – Maple Producer, Ontario

"I harvest my annual fuel supply for my evaporator from my sugar bush. I enjoy the work and save on energy costs." – Maple Producer, Ontario

Introduction

The production of maple syrup is a very important aspect of rural life for many families in Ontario. Early each spring men, women and children take to the woods to participate in the yearly tradition of tapping trees and boiling sap. For many, it is part of their heritage, steeped in history and closely linked to family values. For others, maple production is a business providing an important portion of their annual income. Still for others, it is a new activity or hobby which presents a unique set of challenges as skills are learned and new traditions are developed.

Many sugar bushes in Ontario have been tapped for generations. Some operations have been in continuous production for over 100 years. This demonstrates the sustainability of sugar bushes and associated production facilities. This sustainability can be assured in the future if sugar bushes are cared for in a manner consistent with the principles and practices described in this publication.

This manual is a comprehensive guide for sugar bush operators interested in improving and maintaining a healthy and productive sugar bush. It was developed primarily for use by commercial maple producers, or individuals who will own and/or manage a commercial maple operation in the future. Due to its comprehensive nature, it is intended for use as a reference on particular aspects of sugar bush management, depending on the interest. For example, if the interest is in major forest pests affecting sugar bushes, the maple producer will read that particular section. At another time, their interest may be in developing a plan for the sugar bush and they will use pertinent materials related to planning.

The publication will also be a valuable reference for forest resource professionals and teachers responsible for delivering educational programs focused on sugar bush management.

The overall goal is to encourage the development of written plans for the sugar bush and to expand adoption of best management practices in the sugar bush by maple producers. The practices recommended are designed to maintain and/or enhance the health of the sugar bush as well as its production capacity for sap and other secondary products. Application of the practices recommended in this publication will help ensure that maple operations will remain economically viable in the long-term. At the same time, the health and productivity of the sugar bush will be maintained and enhanced.

Some management philosophies and practices have changed dramatically over the past 20 years. *A Guide to Improving and Maintaining Sugar Bush Health and Productivity* was developed taking into account these changes and the results of research and operational experience accumulated over this time. It also reflects current policy and acceptable practice regarding the use of pesticides and other chemicals in the sugar bush. This publication replaces the Ontario publication entitled *Sugar Bush Management for Maple Syrup Producers*, by Clarence Coons, which was published in 1975.

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Ontario's Maple Syrup Industry

In 2000, Ontario's maple syrup industry produced its most valuable maple crop on record with a farm gate value of 17.7 million dollars.

The production of maple syrup and other maple related products continues to be a very important industry in Ontario which ranks fourth in the world following Quebec, Vermont and Maine. Although the total number of taps has increased from a low of 665 thousand in 1971 to over 1.3 million in 2001, maple syrup is an Ontario food product that is not produced in surplus. As a result, significant opportunities exist for increased production and marketing of high quality Ontario syrup through farm-gate sales, farmers markets, retail stores and specialty gift shops. Today, maple production is the largest farm-based processing industry in the province, providing income for well over 2500 commercial producers.

In 2000, Ontario's maple syrup industry produced its most valuable maple crop on record with a farm gate value of 17.7 million dollars. In recent years, annual production has been an estimated 1,100,000 litres from 1.3 million taps or 0.8 litres per tap.

On average, the maple industry worth an estimated 15 million dollars to Ontario's economy in the sale of maple products. Other more intangible economic values estimated to be worth a similar amount include tourism and the purchase of supplies and services in local economies in Ontario. Farmers benefit from the contribution that maple makes to whole farm income.

Figure 1: Ontario's Maple-Producing Regions

Ontario has a productive and thriving maple industry where trees are tapped early each spring throughout much of the natural range of Sugar Maple. **Figure 1**, above, is a map showing five maple producing regions in Ontario. **Table 1**, opposite page, shows the total number of taps for each region as well as the average number of taps per farm by region as reported in the 2001 Agricultural Census Data.

Figure 2: Ontario's Counties by Number

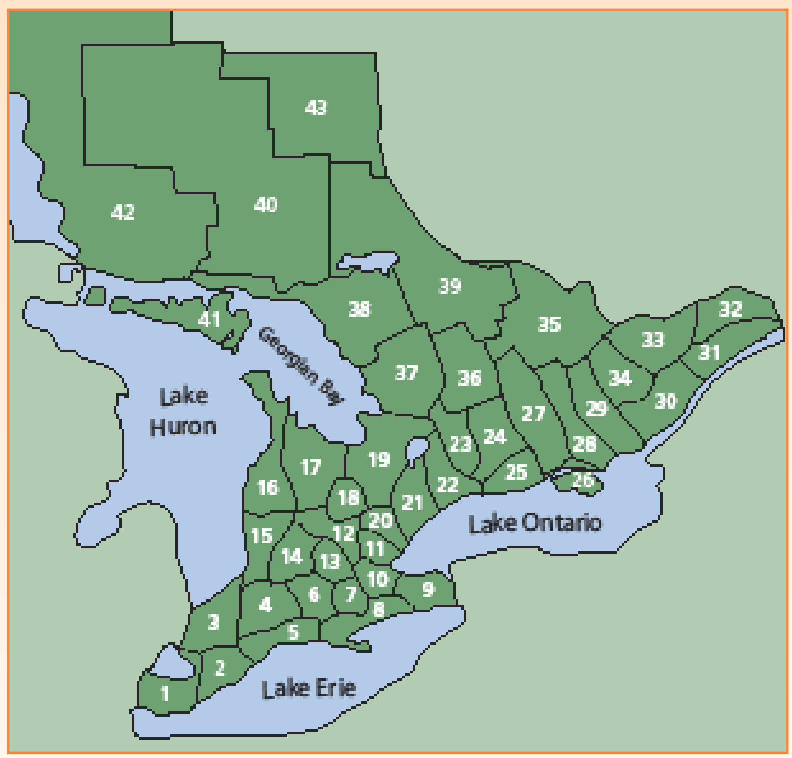


Figure 2, above, is a map showing the location of Ontario's 43 maple producing counties. **Table 2**, pages 2-3, lists the total number taps for each county as well as the average number of taps per farm by county as reported in the 2001 Agricultural Census Data. The colour used in the first column of **Table 2** links the county to one of the five regions displayed in **Figure 1**.

Table 1: **Ontario's Maple Industry by Region 2001**

Region	No. of Taps	Aver. Taps per Farm
Southern Ontario Region	136,315	417
Western Ontario Region	464,093	432
Eastern Ontario Region	340,406	595
Central Ontario Region	269,617	519
Northern Ontario Region	94,564	985

Table 2: **Ontario's Maple Industry by County**

County Number	County	No. of Taps	Aver. Taps per Farm
1	Essex County	289	72
2	Chatham-Kent Division	10,711	714
3	Lambton County	13,994	359
4	Middlesex County	44,207	762
5	Elgin County	17,925	472
6	Oxford County	16,874	234
7	Brant County	3,128	284
8	Haldimand-Norfolk Regional Municipality	21,105	480
9	Niagara Regional Municipality	5,039	219
10	Hamilton Division	3,043	132
11	Halton Regional Municipality	3,981	199
12	Wellington County	47,093	262
13	Waterloo Regional Municipality	151,130	532
14	Perth County	23,972	296
15	Huron County	80,460	688
16	Bruce County	47,707	422
17	Grey County	46,646	348
18	Dufferin County	9,402	303
19	Simcoe County	47,759	468
20	Peel Regional Municipality	5,943	495
21	York Regional Municipality	3,780	135
22	Durham Regional Municipality	8,481	184
23	Kawartha Lakes Division	22,682	354
24	Peterborough County	30,412	428
25	Northumberland County	17,489	336
26	Prince Edward Division	22,082	526
27	Hastings County	34,782	355

continued on following page

Table 2 continued: Ontario's Maple Industry by County

County Number	County	No. of Taps	Aver. Taps per Farm
28	Lennox and Addington County	12,604	341
29	Frontenac County	38,360	629
30	Leeds and Grenville United Counties	67,977	654
31	Stormont, Dundas and Glengarry Counties	36,773	478
32	Prescott and Russell United Counties	23,616	446
33	Ottawa Division	11,437	266
34	Lanark County	110,218	1,185
35	Renfrew County	39,421	379
36	Haliburton County	16,920	846
37	Muskoka District Municipality	11,620	332
38	Parry Sound District	101,369	1,609
39	Nipissing District	10,852	678
40	Sudbury District	875	175
41	Manitoulin District	3,278	182
42	Algoma District	76,419	1,661
43	Timiskaming District	997	249

Assorted maple products

Background: Boiling sap

Early Maple Production and Management

Maple syrup has been made within the natural range of the Sugar Maple for many centuries. It is one of the earliest known agricultural crops in Canada and the United States, having been produced for many years before the arrival of explorers to North America.

It is not known when the first maple tree was tapped for its sweet sap or how the discovery was made, but there are a number of legends describing the event. One popular legend tells of an Indian chief named Woksis and his wife. Woksis' wife cooked their venison one evening in liquid she had found in a vessel at the base of a maple tree. Sap had dripped into the container from a gash in the tree where Woksis had thrown his tomahawk the night before. The sap boiled down to maple syrup during the cooking process, resulting in a surprisingly sweet and flavourful meal. The source of the sweetness was realized, marking the beginning of the tradition of maple sugaring.

Early explorers to North America observed Indian women tapping maple trees as early as 1555. Other trees were also tapped, including birch, Manitoba Maple, Sumac, Sycamore, Basswood, Black Walnut, Hickory, and Butternut. The sap of the maple tree was observed to flow abundantly and had the most pleasant flavour and colouring when boiled down. Explorers wrote home with stories of maple sugar, suggesting that maple trees back home be tapped. The absence of Sugar Maple and differences in climate made this impossible.

Maple sugaring has always marked the end of winter and the beginning of a new growing season. Winters were long and difficult for aboriginal people and early European settlers. Because of this, spring was greatly anticipated and maple sugaring was a time for celebration.

Note the wooden spouts and birch bark buckets

Early method: log trough for sap reduction

The illustration at left, adapted from a very early photo, depicts a typical aboriginal sugar camp after the arrival of the European settlers (note their kettle and European clothing). These native women have moved on from earlier methods which used hot stones dropped into syrup in log troughs. (inset).

Indian sugar camps were cheerful and filled with laughter as the women and children worked in the maple bush.

Maple Production by Aboriginal Peoples

Aboriginal peoples would move from their winter hunting grounds to their sugar bush camps each spring. Women and children were primarily responsible for maple sugaring activities while at the camp. The men would hunt and busy themselves with other activities while the women and children looked after collecting the sap and tending the fires. The women would make sap buckets from birch bark or hollowed out sections of solid wood. The more buckets that a woman had, the more elite the status she possessed. Some women had as many as 1500 buckets. Aboriginal sugar camps were cheerful and filled with laughter as the women and children worked in the maple bush.

Meals in the sugar camps were centered on maple. The women and children feasted on fresh syrup and sugar as they worked and one man could consume as much as one pound of maple sugar per day and little else on a hunting trip. A year's production did not last until the next year. It was feast or famine, with large quantities of maple consumed until their supply was exhausted. Most of the sap was made into a grainy sugar that was kept in large baskets for every day use. Solid cakes of sugar, some with intricate designs, were used for gift giving and for bartering. Trade was conducted with other tribes and later on with fur traders and neighbouring settlers.

Early wooden sugar molds

Maple Production by Settlers

By the middle of the 1800's, the yearly sugar bush activities of the aboriginal people were quite popular with settlers in the area. Unlike in the aboriginal sugar camps, maple sugaring was primarily the work of men and boys. Each family owned their own land and the maple trees on it, contrasting with the communal nature of sugaring activities in the aboriginal sugar camps. It did remain a social affair with families and neighbours getting together to help and to socialize.

Sugar making fit easily into farming life. With planting in late spring, cultivation in the summer, harvest in the fall, and cutting fuelwood in the winter, sugar making came at a time when other farm chores were at a lull. The hearty exercise was often a welcome change after a long winter. Most farmers tapped on a small scale in the 1800's, with 300 to 500 trees tapped being a hard season's work for sugaring.

Early sap collecting

Maple sugar is the first farm crop of the year to be produced. It was considered a cash crop by settlers because no great investment was required. Money from the sale of maple sugar and syrup was often used for the purchase of seeds or for paying taxes.

White sugar was scarce and very expensive as it was imported from the West Indies. Because of this, a great number of farmers took advantage of their maple trees to produce their own maple sugar rather than spending their scarce funds on white sugar. Any extra product from the farm, including maple sugar, was sold or bartered in order to obtain items that could not be produced on the farm.

In the 1800's maple sugar was half the price of cane sugar. By 1900, new technologies had been developed for refining cane sugar that made it cheaper to manufacture and thus cheaper to buy than maple sugar. The technology for production and the availability of maple sugar has never been such that it could compete with cane sugar on the world market. This has made maple syrup and maple sugar more of a luxury item, often produced for income generating purposes rather than predominantly for personal consumption.

Maple Sugar Production as an Industry

As rural Ontario was settled, maple sugar production steadily increased. It reached a high of 3,168,000 kilograms (6,970,605 pounds) in Ontario in 1861. By 1882 however, production had decreased to 2,306,000 kilograms (5,073,610 pounds) due to clearing of the land for farmland and increased availability of cheaper cane sugar.

World War I and World War II resulted in an increased demand for maple sugar, stimulating increases in production. During World War II in particular, cane sugar was in short supply and was rationed. The government fixed the price of maple syrup at $3.39 per gallon and directed labour into maple production to increase the amount of maple sugar available.

The Ontario Maple Syrup Producers' Association (OMSPA) was formed in 1966. This development helped to establish maple production as an industry, allowing producers greater access to information and resources. The first commercial packers were also established around this time.

The instrument above, called a 'sugar devil' was used to break up solid maple sugar in a maple sugar barrel into smaller pieces that could be used for cooking. It was simpler and quicker for personal, every day use to have a barrel of maple sugar and work away at it than use sugar molds to have shaped pieces of maple sugar.

The first third of the 20th century brought changes in maple production. Flue evaporators became widely used for maple production. Farms started to become more specialized, resulting in fewer farms producing their own maple syrup as part of their farming activities. Producing maple syrup for the purpose of selling it for profit became more popular. Between 1900 and 1940, the first attractive, coloured syrup cans were produced to aid in the endeavour of marketing and selling maple syrup.

Very old syrup tins, centre one hand-soldered

The Ontario Maple Syrup Producers' Association (OMSPA) was formed in 1966. This development helped to establish maple production as an industry, allowing producers greater access to information and resources.

The History of Sugar Bush Management in Rural Ontario

Although maple production has a long history in Ontario, it was not until the mid 1970's that the management of the sugar bush took on more importance for producers.

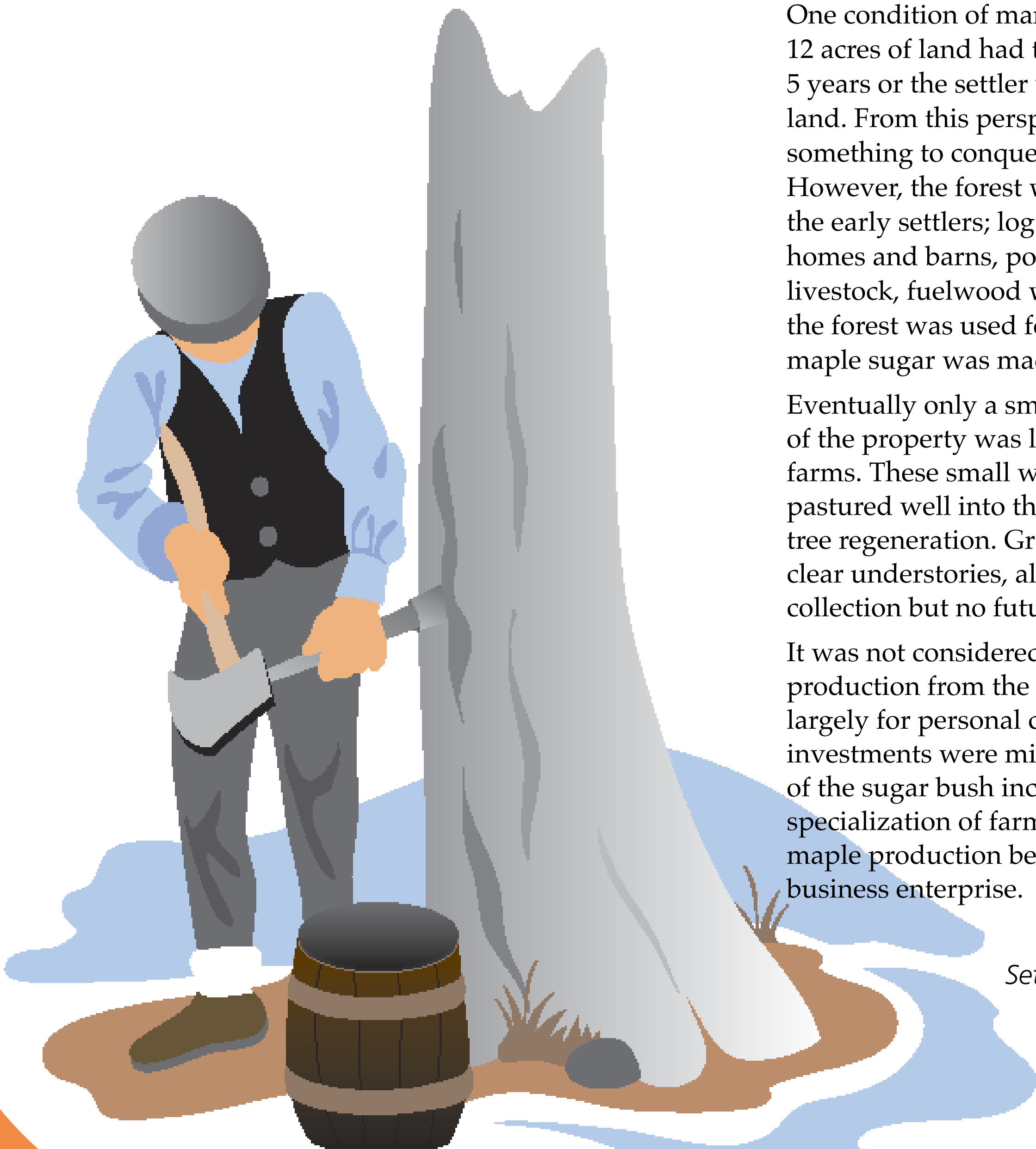
Managing the sugar bush was not a concern for the aboriginal people. They had many trees to choose from and could move from stand to stand as they needed. Tapping involved making a gash in the tree with a tomahawk and inserting a chip of wood at the bottom of the gash to allow the sap to drip into a container at the base of the tree.

These tapping methods resulted in wounds that could eventually kill a tree if tapped heavily for many years. The settlers continued with basically the same tapping methods for a number of years, using axes, augers, or gouges for tapping, but the use of axes was eventually eliminated due to the damage caused to the trees.

Forest management was not a priority in the days of the settlers either. New settlers had to quickly adapt to the land and learn to survive in their new country. They were faced with the difficult task of clearing the land for farming. One condition of many land grants was that 12 acres of land had to be cleared within 5 years or the settler would lose title to the land. From this perspective, the forest was something to conquer rather than manage. However, the forest was also a lifeline for the early settlers; logs were used to build homes and barns, poles were used for fencing livestock, fuelwood was used to heat homes, the forest was used for grazing livestock and maple sugar was made.

Eventually only a small woodlot at the back of the property was left uncleared on many farms. These small woodlots were often pastured well into the 20th century, limiting tree regeneration. Grazed sugar bushes had clear understories, allowing for easy sap collection but no future replacement of trees.

It was not considered important to maximize production from the sugar bush as it was largely for personal consumption and the investments were minimal. Management of the sugar bush increased with the specialization of farming activities, as maple production became more of a business enterprise.



Settler tapping

Woodland management changed with the introduction of tubing systems. The need for extensive travel through the sugar bush for daily sap collection was largely eliminated, resulting in reduced soil compaction and damage to the roots of the trees.

The Ontario Maple Syrup Producers' Association and the Ontario government have placed emphasis on sugar bush management through the development of publications and fact sheets, as well as the sponsorship of various research projects. The predecessor to this manual, titled *A Sugar Bush Management for Maple Producers* was first published in 1975. In addition, numerous educational activities such as 'Maple Information Days' have been carried out in part to fulfill a need for more information on how to properly care for the sugar bush.

Many maple producers have realized the benefits of management and are thinning their sugar bushes to improve health and productivity. In addition to the benefits of stand improvement, better markets for fuelwood since 1975 have helped sugar bush operators justify the time and expense associated with thinning activities. Many maple producers also mention that they enjoy working in the sugar bush and seeing the excellent growth response of the young trees which are provided with more light and space to grow. For some producers, this is their main motivation and justification for their sugar bush management efforts.

Over the years, our understanding of how the sugar bush grows and how growth is linked to productivity has increased greatly. Some of the practices which were once commonly recommended have been proven to be inappropriate or even damaging to the long term health of the sugar bush. There has been a considerable amount of maple research in Ontario as well as in other jurisdictions which has lead to our current recognition of the importance and viability of good management practices. A carefully managed sugar bush can remain productive for many generations. Sugar bushes are currently managed for both present and future sap production with added benefits of such things as fuelwood, sawlogs and wildlife habitat. Future research will help keep Ontario's sugar bushes healthy and productive through the continued improvement of management techniques.

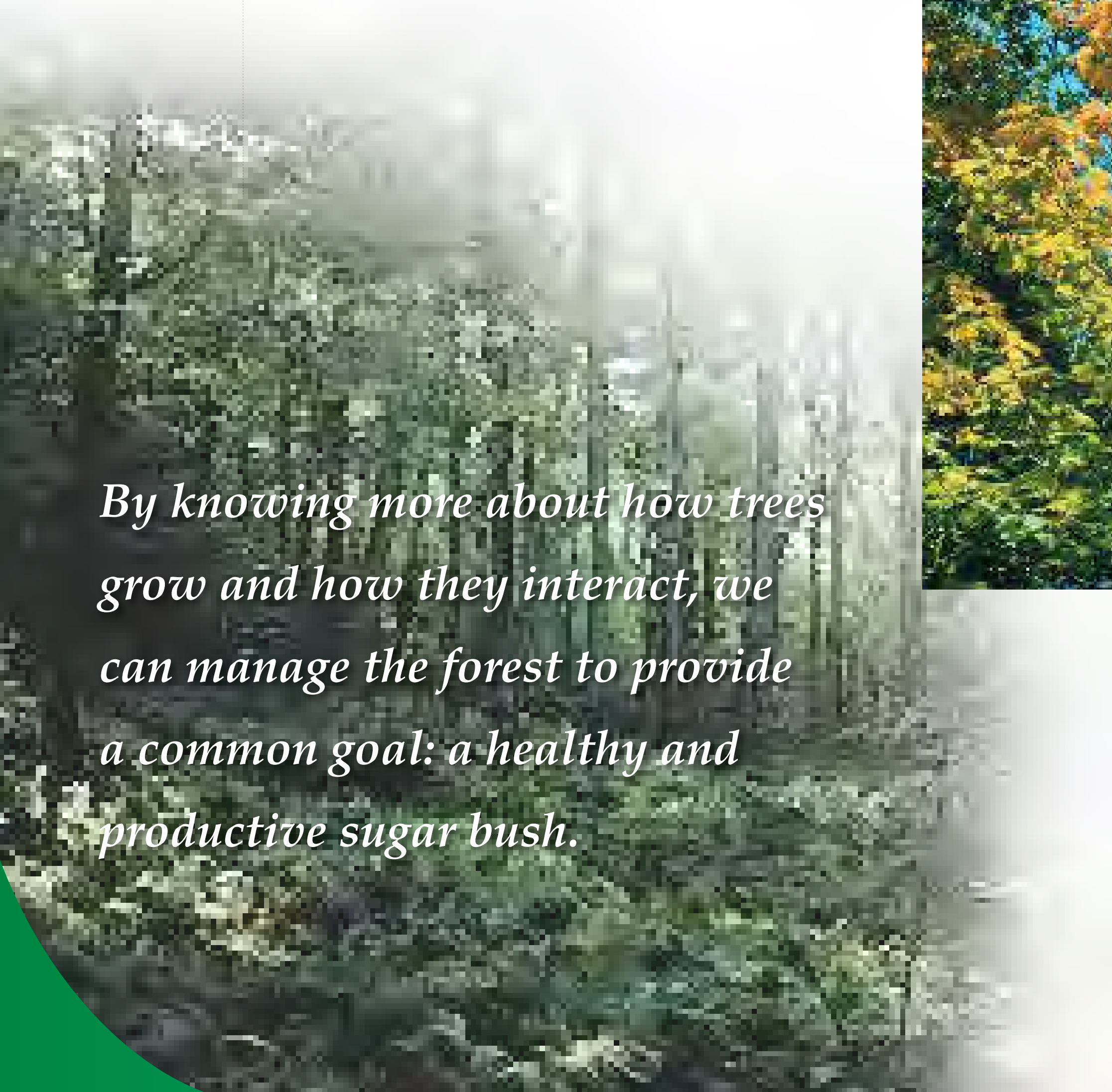
Future research will help keep Ontario's sugar bushes healthy and productive through the continued improvement of management techniques.

4 Maple Health and Productivity

All trees, including maple, have a number of specific characteristics which govern their growth and survival. Some species are common on dry sites, while others can only be found on wetter soils; other trees can only reproduce under complete sun and will not survive in shade. It is these characteristics which determine where trees grow, how our forests evolve over time and how they react to management. It is also these characteristics which become the foundation for management decisions.

For the maple producer, management activities are aimed at manipulating the sugar bush to take advantage of these characteristics. We manage our sugar bushes to do such things as provide growing space, promote regeneration and to lessen the impact of insects and disease. By knowing more about how trees grow and how they interact, we can manage the forest to provide a common goal: a healthy and productive sugar bush. Ignoring adaptations can cause numerous problems. Poor management decisions are those which do not capitalize on the natural ability of the trees to grow and reproduce, or limit the natural productivity of individual trees and/or the sugar bush as a whole.

This section details many of the characteristics unique to maple species and maple dominated forests.



By knowing more about how trees grow and how they interact, we can manage the forest to provide a common goal: a healthy and productive sugar bush.

Background: Stand of Sugar Maple

Inset: Young Sugar Maple in early fall

CHARACTERISTICS OF MAPLE SPECIES

There are seven species of maple that grow in Ontario. Two of these, Sugar Maple (*Acer saccharum Marsh.*) and Black Maple (*Acer nigrum Michx.*) have the sweetest sap and produce the vast majority of the maple syrup made in the province. Occasionally, Red Maple (*Acer rubrum L.*) and even Silver Maple (*Acer saccharinum L.*) are tapped but they generally have a lower sugar content.

Of these four species, Sugar Maple is most prevalent and is tapped extensively on a commercial basis throughout the southern and central part of the province (Figure 3). Sugar Maple tends to be a high yielding sap producer which grows on a wide variety of sites throughout its range. Black Maple, which is found in the southern portions of the province, is also a high yielding sap producer but its occurrence in sugar bushes is far more limited than Sugar Maple.

Sugar Maple

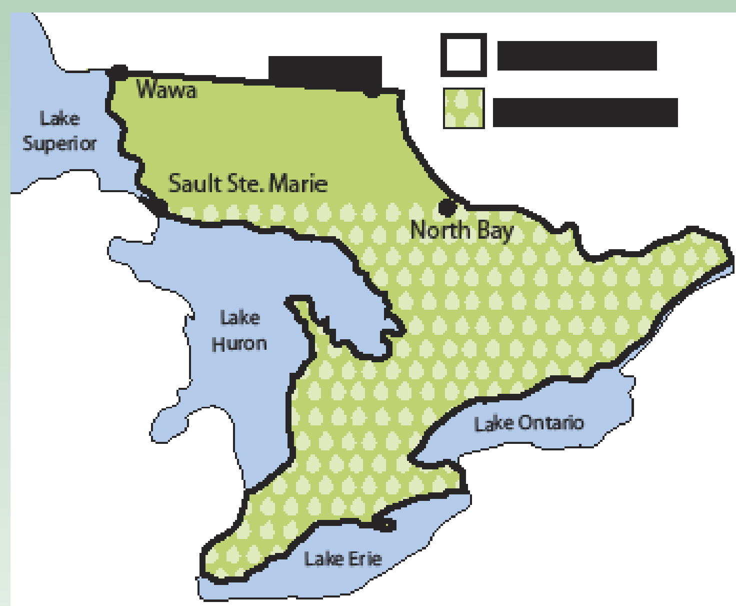
Sugar Maple tends to dominate many of the hardwood forests in which it is found. Although there are a number of specific reasons for this, Sugar Maple are usually better adapted to local site conditions and as a result, will simply out-compete other species which may be found growing on the same site. Maple is also a valuable tree for the production of syrup, flooring, lumber and firewood and its growth has been promoted throughout Ontario. Individual trees which are the best adapted to the site tend to grow more vigorously. As a result these trees may be in a better position to overcome the effects of environmental stresses brought on by such things as weather and insects.

Range of Sugar Maple

Sugar Maple, like other tree species, grow within a geographic range where conditions are favourable for their survival and reproduction. The size and location of this range is influenced by three factors – physical geography (soils, bedrock, and topography), climate and history. In areas where these factors are ideal, maple will thrive and can often out-compete other species for dominance in the forest. In areas where one or more of these factors are limiting, maple will survive but may not dominate over other species.

Sugar Maple, like other tree species, grow within a geographic range where conditions are favourable for their survival and reproduction.

Figure 3: **Botanical and Commercial Range of Sugar Maple in Ontario**



Sugar Maple is found throughout southern Ontario and extends north to a line from Wawa to Temagami. The northern edge of the commercial range extends from Sault Ste. Marie to North Bay. The botanical range also extends into northwestern Ontario (not shown on this map).

Over the millennia, tree species have evolved to survive within a range of climatic conditions. One of the reasons Sugar Maple is so successful in many southern Ontario forests is because it adapted to a wide range of climatic conditions.

Some climatic conditions influencing the natural range of Sugar Maple

- Temperature extremes from -40°C to +38°C (-40ºF to 100ºF)
- Annual precipitation from 510 mm to 2030 mm (20.4 in to 81.2 in)
- Annual growing degree days from 80 to 260 days
- Spring frosts from March 20th to June 15th
- Killing frosts from September 1st to November 10th

One of the reasons Sugar Maple is so successful in southern Ontario is because it can grow on a wide variety of soil types.

Soils and Topography

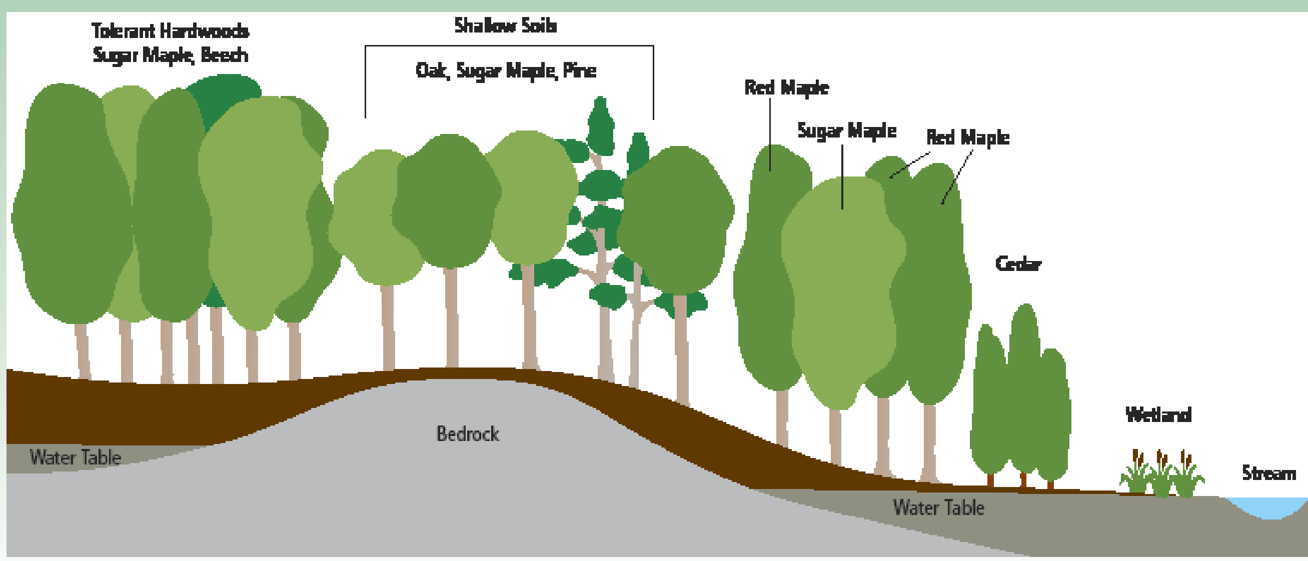
The health and productivity of a sugar bush is strongly influenced by the characteristics of the soil on which it is growing. Soil is primarily weathered rock material that has been broken down by either wind or water into individual particles. Ontario soils have been re-distributed by successive ice-ages. Forest soils also contain varying amounts of organic matter (humus, fungi, worms, insects, animal remains, etc.), water and air. Together, these properties provide the trees and other plants physical support, moisture and nutrients. Different species of trees have different soil requirements – some grow better on sandy dry soils while others prefer moist loamy soils.

One of the reasons Sugar Maple is so successful in Ontario is because it can grow on a wide variety of soil types. However, it grows best on well-drained loams with a pH range of 5.5 to 7.5. It also favours soils with abundant organic matter. Additional information on the suitability of soil types for Sugar Maple is provided in the Maple Orchards section of this manual.

Sugar Maple is typically found on well drained ridges and extensive level plains, on soil with depth to the water table of at least 1–1.5 m (3.25–5.00 ft).

Figure 4: Site and Soil Impacts on Species Associations

Figure 4 demonstrates how Sugar Maple grows on a number of different site types. Note how it can dominate a site under ideal conditions



Reproduction

Flowering and seed production begins once trees reach 20 years. Seeds ripen in about 16 weeks, with usually only one of the paired winged "samaras" bearing a seed. The wings allow the seed to be carried up to 100 m (300 ft) from the tree by wind, and their spinning helicopter action helps them penetrate thick litter layers.

To germinate, the seeds must undergo moist stratification at temperatures slightly above freezing for 35–90 days. This stratification occurs over the winter. Optimum seed germination temperature in the spring is 1°C (33.8°F) and growth and leaf production generally begins before all of the snow has left the sugar bush. Once the seed germinates it produces a strong first root (radicle) which penetrates through thick litter layers to reach mineral soil.

Sugar Maple is a prolific seed producer; however, not all of these seeds germinate and reach maturity. Seed and seedling survival is limited by poor germination conditions, browsing, very dry weather and lack of release from competition.

Seedling Development

Sugar Maple seedlings are very shade tolerant and can survive for long periods in the understory without release. Best seedling growth is observed under partial shade (65% shade), and most growth occurs within the first 20 days after leaf out. Large seed numbers often result in large seedling numbers, up to 370,000 seedlings/ha (150,000 seedlings/acre) are common. In dense young stands seedlings may only survive for 5 years, but in older stands they can persist much longer, but will often not grow much until released.

Figure 5: Suppressed Maple in the Understory

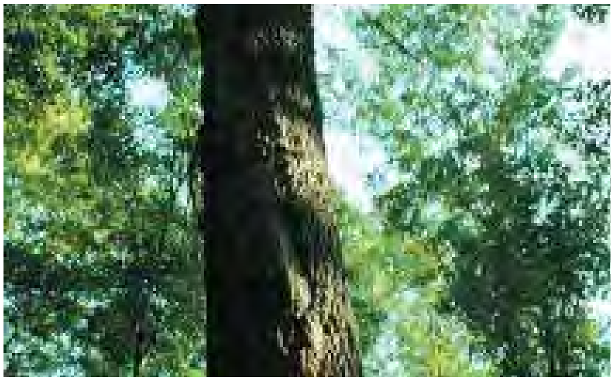
Even shade tolerant trees like maple require some direct sunlight for their survival. Saplings growing for many years in the shade of a closed-in canopy will tend to develop a characteristic 'flat topped' shape unless they are able to get sunlight directly from above. Once a tree has developed this shape, it will not be able to respond well if it is released.

Vegetative Reproduction

Sugar Maple does not usually successfully reproduce vegetatively by stump sprouts or root suckering, although both do occur especially after heavy cutting. The proportion of stump sprouts decreases with increasing tree size and stand density.

Sapling to Maturity

Sugar Maple grows slowly when young in part because it is adapted to growing in shade. Growth of polewood-sized trees is also slower than other hardwood species. Diameter growth of 5 cm (2 in) per 10 years can be expected from polewood and older trees on some sites. Height growth averages 30 cm/year (12 in/year). Although often limited by declining tree health, natural disturbance or management intervention, mature Sugar Maple can reach a maximum of 300–400 years of age, and average 27–37 m (89–128 ft) in height and 76–91 cm (30–36 in) diameter at maturity. Continuously tapped trees often live for 100 or more years in the sugar bush: what other crop on the farm is productive for this long?

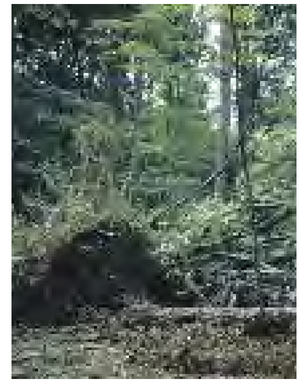


Continuously tapped trees often live for 100 or more years in the sugar bush; what other crop on the farm is productive for this long?

Rooting Habits

Sugar Maple roots grow primarily parallel with the soil surface, with the upper lateral roots reaching into the humus layers and the lower lateral roots growing down towards water. The majority of fine roots are found within 60 cm (2 ft) of the soil surface making maple sensitive to problems caused by rutting and compaction. Windthrow can be a problem on some shallower sites or in severe windstorms even on productive sites. Sugar Maple roots are very sensitive to flooding during the growing season which can contribute to tree decline.

Uprooted Sugar Maple after a severe wind storm



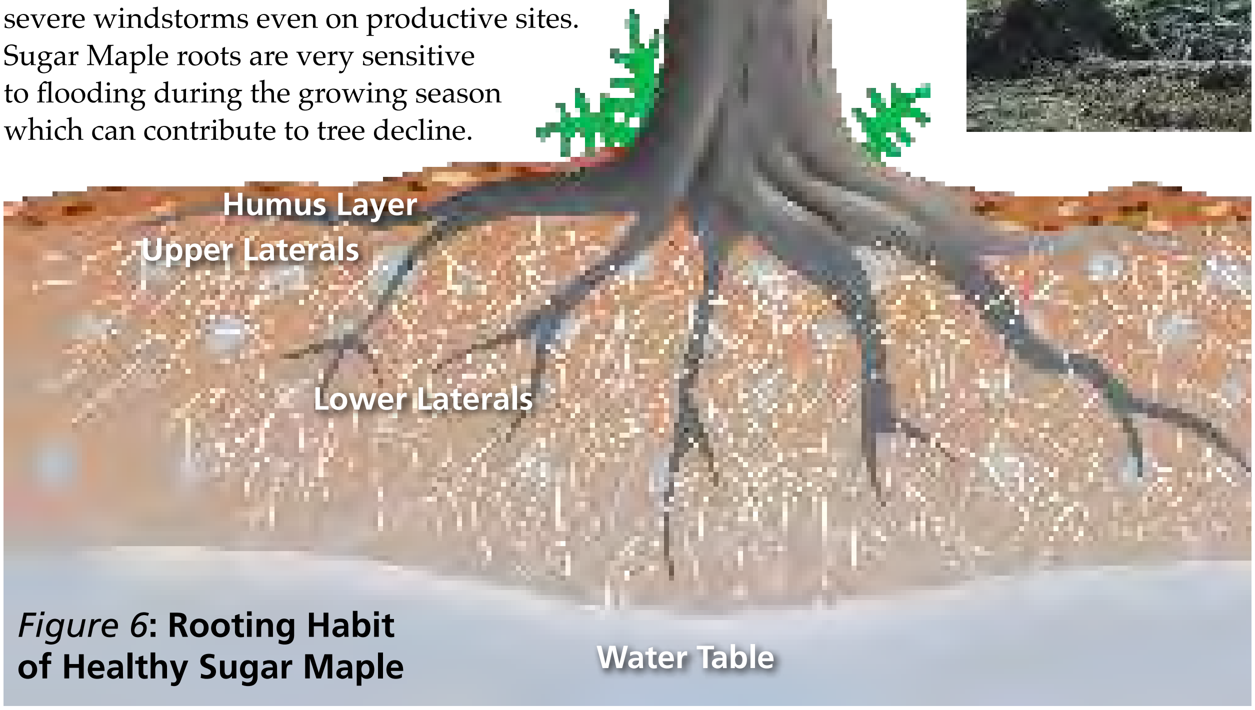


Figure 6: **Rooting Habit of Healthy Sugar Maple**

Reaction to Competition

Sugar Maple is very shade tolerant. It can survive for long periods without release and reaches maximum photosynthetic rates at 25% of full sunlight.

Healthy sapling and polewood stands have been found to double their diameter growth when trees are released. However, excessive release will cause dormant buds to sprout on the stem potentially reducing future log value.

Sugar Maple stand in summer

Open-Grown Versus Forest-Grown Sugar Maple

Competition from neighbouring trees is one of the strongest influences on tree form (shape). Under forested conditions, competition forces a tree to grow toward sunlight. Branches which are shaded at the bottom of the crown eventually die and the crown develops its compact forest-grown shape. Under open conditions, trees are not subject to direct competition and as a result, they tend to develop a crown which is much larger than forest-grown trees.

Figure 7: **General Crown Shape for Open- and Forest-Grown Sugar Maple**

Crown size has historically been linked to sap volume and to some degree, sap sweetness where larger crowns are thought to be better sap producers. Open-grown Sugar Maple are often highly prized as bountiful producers of sweeter than average sap and are termed 'sap cows' by many old timers. Sugar bush management techniques promote larger crowns by keeping the stand at a lower density than what is recommended for timber production. In the managed sugar bush, trees are spaced further apart providing more room and additional light at lower levels of the crown. Higher light levels may improve photosynthetic efficiency resulting in higher sap sweetness. Many orchard trees are producing sap which is sweeter than the sugar bush from which they were originally transplanted.

Although not completely open-grown, the lower density of the managed sugar bush allows trees to maintain larger crowns which may result in greater overall sap productivity. However, not all sap volume and sweetness differences can be attributed purely to crown volume and light levels. Other factors such as site and location, as well as tree genetics also factor into why some trees, and some sugar bushes, are more productive than others.

- **Site and Location** – site factors like moisture regime, soil depth, soil parent material, and fertility status can influence overall productivity. These factors are discussed in detail throughout this manual. Many of the open grown trees along Ontario's roadsides were planted in the late 19th century by township programs. These trees were often planted on prime agricultural land, in other words a superior site type to many of the residual sugar bushes left on the landscape. Superior site should lead to superior growth and vigour, and also superior sap volume production.
- **Genetics** – The seed source of many of these transplants is probably some of the biggest and best trees of the virgin forest that were being tapped in the mid 19th century. These trees may have superior genetics compared to the seed sources of today. High grading of woodlands has removed much of the best genetic stock, and the trees producing sap today may be genetically inferior to the original stock. These genetic differences may result in greater sap flow and higher sap sweetness in roadside trees.

Open-grown Sugar Maples

Total Leaf Biomass

A tree will have a **total leaf biomass** that is proportional to its diameter; trees with smaller diameters will have proportionally smaller leaf biomass while trees with larger diameters will have proportionally larger leaf biomass. In the diagram (right) this relationship is represented by the green line (**B**); all trees will fit on or near this line (greyed zone). A tree can not survive below this zone (**C**) where there is not enough leaf biomass to support life. It is also not possible to find a tree above this zone which would represent surplus production.

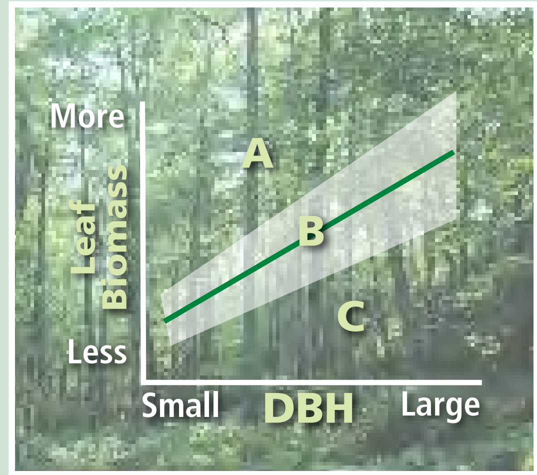


Figure 8: **Total Leaf Biomass by Diameter**

Characteristics of Other Maples

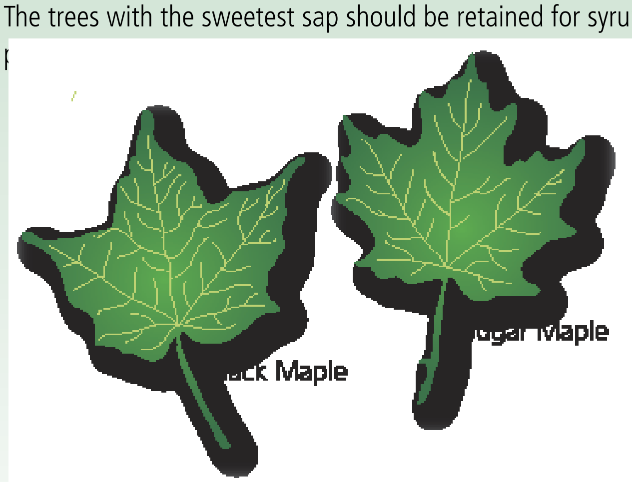
Although Sugar Maple is the most commonly tapped species, three other species, Black Maple, Red Maple, and Silver Maple are tapped, and have the potential to produce sap in your sugar bush. These other three species also have unique characteristics which allow them to adapt to their environment. Even though both Red and Silver Maple may not produce as much sap volume or sweetness as Sugar Maple, a healthy vigorous Red Maple on a moist site is preferable to a stagnating/ declining Sugar Maple.

A Comparison of Black Maple and Sugar Maple Characteristics

Black Maple *(Acer nigrum)* is a close relative of Sugar Maple. Black Maple is found throughout southern Ontario, although it has a smaller native range than Sugar Maple. In eastern Ontario it is sporadically found on drier upland sites such as the Smiths Falls limestone plain but can also be found on deeper more fertile soils. In southwestern Ontario, Black Maple is more commonly found on river floodplains.

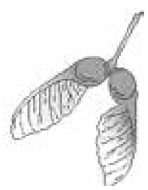
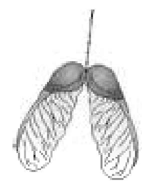
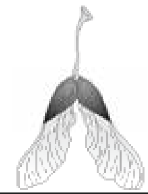
The two species are almost indistinguishable except for leaf characteristics. Black Maple leaves are usually three-lobed and occasionally five-lobed, while Sugar Maple leaves are five-lobed. Also, there is a "pelty" feel to the underside of the leaves of Black Maple and some hairiness is usually quite visible. Leaves often appear to be drooping. The two species do hybridize or interbreed and where their ranges overlap the complete gradient from pure Sugar Maple to pure Black Maple can be found. The hybrids will show characteristics of both species. Lumber and firewood characteristics are identical for the two species.

Black Maple has a reputation for having sweeter sap than Sugar Maple but there is no scientific evidence to back this up. Both species will range widely in sap sugar content and volume production, and producers are encouraged to test each tree individually as described elsewhere in this manual. The trees with the sweetest sap should be retained for syrup p



Knowing the characteristics of these other maple species can help you make important thinning and management decisions. The characteristics of four commonly tapped maple species are outlined in Table 3.

Table 3: **Characteristics of Commonly Tapped Maple Trees**

Species	Sugar Maple	Black Maple	Red Maple	Silver Maple
Leaf profile				
Seed profile				
Tree longevity (years)	300	200	80	130
Soil moisture preference	fresh	fresh-moist	moist	wet
Soil nutrient preference	high	high	medium	very high
Tolerance to flooding	low	low	medium	high
Preferred seedbed	leaf litter	leaf litter	leaf litter	leaf litter
Shade tolerance	very tolerant	very tolerant	tolerant	intolerant
Response to release	very high	very high	very high	high
Age of first seed crop	22–30 years	unknown	4 years	11 years
Seed crop	3–7 years	4 years	1–2 years	1 year
Seed dispersal method	wind 100 m	wind 100 m	wind 100 m	wind 200 m
Seed dispersal period	June – Sept.	Sept. – Oct.	June – July	April – June

Characteristics of Maple Stands

Associated Species

Maple trees are naturally found in association with other tree species that have similar characteristics. The types and abundance of species present in your stand are dependent on:

- Site characteristics including geographic area, past natural disturbance and soil properties; variable sites will promote greater species diversity.
- Previous management history: species can effect composition and tree quality, and other tree characteristics.
- Characteristics of the individual species

In some stands, maple may dominate or even be the only species in the stand – most sugar bushes are found in these types of stands, where maple makes up at least 25% of the forest canopy. In other stands, maple may only be a minor component of the overstory but may, or may not, dominate in the understory.

You can make predictions about the future of a stand by knowing the characteristics of the trees growing on site. If, for example, you have a stand which is mostly oak in the overstory but the understory is dominated by young maple seedlings, you can predict that because maple is well adapted to survival in shade, there will be an eventual species conversion from oak to maple.

The species association which maple is found commonly in, and also often dominates, is termed the Tolerant Hardwood Working Group by forestry professionals. The term 'working group' refers to a loose association of species with similar adaptations and management needs. All the trees in this classification have similar characteristics and are managed in similar ways.

Other working groups also commonly found in Ontario are listed in Table 4. Each one of these working groups contains different associations of species and consequently, recommended management practices.

It is important to recognize that you may find species from other working groups growing in your sugar bush – this does not indicate a problem or that they should be removed through harvesting. Many species, including maples, grow under a wide range of conditions and can often be found on a site which would not be considered ideal for that species. For example, many sugar bushes in eastern Ontario also contain some White Cedar; this does not make it a cedar site unless cedar dominates in the stand.

Hemlock in a stand of Sugar Maple

Table 4: **Common Species Associations Found in Ontario.**

Working Group	Major Species	Other Species Commonly Found	Sugar Bush Potential
Tolerant Hardwoods	**Sugar Maple,** American Beech, **Black Maple**	White Ash, Basswood, Yellow Birch, Hemlock, Bitternut Hickory, **Red Maple**, Cedar, Pine, Oak	Yes – most of Ontario's sugar bushes are found in this type of stand.
Lowland Hardwoods	**Red Maple, Silver Maple,** Green Ash, Black Ash	Yellow Birch, Trembling Aspen, White Cedar, Balsam Fir, White Birch, **Sugar Maple**	Yes – there are some maple producers in Ontario who get most of their sap from Red Maple
Upland Oak and Pine	Red Oak, White Oak, White Pine	White Ash, **Sugar Maple, Black Maple**	Seldom, although maple stands will often abut this type of stand allowing for some tapping of maples near the stand boundary
White Cedar	White Cedar	**Red Maple**, **Sugar Maple**, Basswood, Hemlock, Poplar, Birch	No
Early Successional Species	Trembling Aspen, Largetooth Aspen, White Birch	Black Cherry, Green Ash, White Pine, **Sugar Maple**	No. Early successional stands do, however, act as a nurse crop for young maple trees.
Hemlock	Hemlock	**Sugar Maple**, American Beech, White Ash, Basswood, Yellow Birch, **Red Maple**, Cedar	Seldom, although Hemlock stands are usually small and are often found in or near operating sugar bushes. These stands offer some potential for tapping.

There are six species which are commonly found with Sugar Maple throughout its range in Ontario. These species are listed in the first column of Table 5. There are a number of other species which are more specific to different parts of the province but are also commonly associated with Sugar Maple.

Ontario is divided into a number of different *Site Regions* which are broad areas of similar climate and landform. Trees growing in a particular site region will have similar growth characteristics, biological productivity, and potential for forestry purposes. In Southern Ontario, there are three site regions, 5E, 6E, and 7E (Figure 9) in which Sugar Maple is commonly found. A maple growing in site region 7E is adapted to the warmer climate and longer growing season of the region when compared to a maple growing in 5E. This means that on similar sites and under similar stand conditions, the tree in 7E will have more potential to grow faster, taller and larger.

Figure 9: Southern Ontario Site Regions

Table 5: Tree Species Found With Sugar Maple throughout its Natural Range in Ontario

Species common to all zones	Additional species more common to southwestern Ontario (7E)	Additional species more common to south-central and eastern Ontario (6E)	Additional species more common to central and more northerly parts of Ontario (5E)
American Beech Yellow Birch Red Oak, White Ash Black Cherry, Basswood	Tulip Tree, Green Ash Black Walnut Shagbark Hickory Sassafras, Hackberry Pignut Hickory **Black Maple**	**Black Maple**, Ironwood Bitternut Hickory Bur Oak, White Elm Butternut, **Red Maple** Hemlock, White Pine	**Red Maple**, White Pine, White Spruce, Red Spruce, Hemlock

Site Factors

Although Sugar Maple stands can be found on a wide variety of site types, the species grows best on sites described below. On poorer quality sites their growth will generally be much slower and sap yields may also be negatively affected.

The following six factors govern how well Sugar Maple will grow on a particular site.

1. Soil Moisture

Sugar Maple, American Beech and Red Oak grow best on fresh soils that are rapidly, well or moderately well drained. Moister soils promote the growth of Yellow Birch, Red Maple and Hemlock.

Understanding Moisture Regime

All trees use moisture absorbed through their roots from the soil in which they are growing. The **moisture regime** or a particular site, is the relative abundance or availability of soil moisture throughout the growing season. There are four moisture regime classes commonly used to describe how 'wet' or 'dry' a particular soil is:

Dry Soils: Not enough moisture during parts of the growing season for optimum tree growth

Fresh Soils: Optimum moisture conditions for tree growth throughout the growing season

Moist Soils: Too much moisture for optimum tree growth during some part of the growing season

Wet Soils: Too much moisture for Sugar Maple root (tree) survival

Table 6: **Tree Species Commonly Found with Sugar Maple Under Different Growing Conditions (Moisture Regime and Micro Climate).**

Note: Moisture Regime is described on the previous page.

Moisture Regime				
Dry	**Fresh**	**Moist**	**Wet**	**Micro Climate**
Sugar Maple White Spruce Red Spruce Hemlock Red Oak American Beech	**Sugar Maple** Hemlock Yellow Birch White Cedar	**Sugar Maple** Yellow Birch **Red Maple** Hemlock White Cedar	None	Cool
Sugar Maple Red Oak Ironwood Bitternut Hickory Bur Oak White Elm Basswood White Pine (Prickly Ash)	**Sugar Maple** Bitternut Hickory Basswood Ironwood Black Cherry Tulip (7E) Sassafras (7E) Pignut Hickory (7E)	**Sugar Maple** Yellow Birch Basswood Black Walnut Green Ash	None	Warm

Tree species grow on sites which have environmental conditions suitable for their survival. Some species like cooler, wetter environments while other species prefer warm and dry conditions; still others will grow on a number of different site types. One of the reasons Sugar Maple is so successful in Ontario is that it can successfully grow on many different sites which range from cool to warm and from dry to moist. (Table 6)

2. Soil Texture

Soil texture is the relative proportion of sand, silt and clay particles found within a particular soil. It is often depicted in a Soil Texture Triangle (Figure 10). A soil which contains more sand will be a sandy soil. One that contains mostly clay is called a clayey soil and silty soils are primarily made up of silt. A soil classed as a silty sand is one that contains mostly sand and a significant proportion of silt.

Soil texture has a major impact on nutrient availability, soil drainage, and water retention. For example, sandy soils have fewer nutrients, faster drainage and poorer water retention than clay soils. Loams are often an ideal compromise, sharing the best characteristics of both sands and clays.

Although capable of surviving on a wide number of soil textures, Sugar Maple grows best on silty sands, loams, sandy loams, fine sands and silt loams. Coarse sands and heavy clays are not suitable.

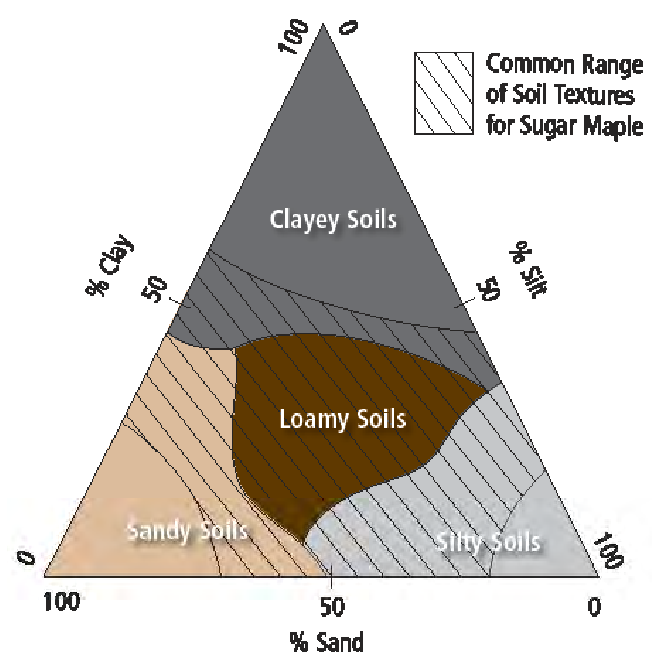


Figure 10: **Soil Texture Triangle**

Table 7: **Site Types Suitable for Sugar Maple**

Legend
- Common
- Uncommon
- Never

Site Type		Moisture Regime			
		Dry	Fresh	Moist	Wet
Soil Texture	Gravelly	Uncommon	Uncommon	Never	Never
	Sandy	Uncommon	Common	Never	Never
	Coarse Loamy	Uncommon	Common	Uncommon	Never
	Fine loamy		Common	Uncommon	Never
	Clayey		Uncommon		Never
	Shallow	Never			Never

It is the combination of moisture regime and soil texture which has the greatest impact on where Sugar Maple will grow, and where it won't. Table 7 illustrates this relationship by listing how common the occurrence of Sugar Maple is on different site types found in Ontario. The five white boxes represent site types not found in the province. Note how Sugar Maple is most commonly found on loamy and sandy soils with the optimum amount of soil moisture for tree growth. As well, this table demonstrates the species intolerance of excessive moisture. It is rarely found on moist and never on wet sites.

3. Soil Organic Content

Sugar Maple requires well decomposed litter and incorporated humus for proper nutrition. Build-up of raw humus and soil acidification and leaching that is prominent under Hemlock and other conifer dominated stands is much less suitable for vigorous maple growth.

4. Soil Chemistry

Sugar Maple grows best with soil pH ranging from 5.5 to 7.5. More acidic soils favour Hemlock and Yellow Birch, while more calcareous soils favour Basswood.

5. Soil Depth and Rooting Restrictions

Although maple trees are commonly found on sites with a soil depth of 15 cm (6 in) and up, a minimum of one metre (3.28 ft) soil depth is required for optimum growth. Maple stands are also frequently found on shallow soils over limestone, dolostone and sandstone type bedrocks. The fractured nature of these sedimentary bedrocks often allows for deeper root penetration and potential access to water reserves. Shallow soils over granitic or other bedrock types are usually occupied by the Pine and Oak working groups. Soils with high water tables are unsuitable for Sugar Maple as growth will be stunted and trees with shallow root systems will be more prone to windthrow.

6. Microclimate

Microclimate is affected by slope aspect (north or south), slope position (top, mid or valley) and also by water features. Hemlock and Yellow Birch are typically found in cooler microclimates, particularly in southern and central areas of the province, and Red Oak, Butternut and Shagbark Hickory are found in warmer microclimates. Sugar Maple is adapted to a broad range of microclimates, being found in cool semi-moist areas such as seepage-ways and warm southern slopes, and most places in-between.

Tree Height as a Measure of Site Quality

Height growth will be superior on sites with the above soil and site characteristics. Figure 11 illustrates the effect of these characteristics on tree height; note that on better sites, trees put on more height at an earlier age than they do on poorer sites. Tree height is a good measure of relative site quality because it has been shown to be largely independent of tree density. **Site Index (SI)** is a relative measure of site quality and is determined by measuring total tree height when a tree is 50 years old; a Sugar Maple with a site index of 20 for example will have a height of 20 m (6.5 ft) at age 50. On better sites the SI will be higher, while on poorer sites it will be lower. Maple is still growing and producing volume on the poorer sites, but at a slower rate. These stands can still be managed but expectations need to be lowered. **Site type** also affects sap production (both volume and sweetness). Sap volume and sweetness production by maple is largely determined by crown volume and tree diameter.

Slower growing maples will produce less sap volume and sweetness over time than rapidly growing maples which will gain diameter and crown volume much more quickly when released. Poor sites also waste individual maple tree resources by forcing the tree to respond to, and recover from stresses such as very dry weather or high water table. Trees on poor sites are usually more defective and managing these stresses can be a strain on tree resources.

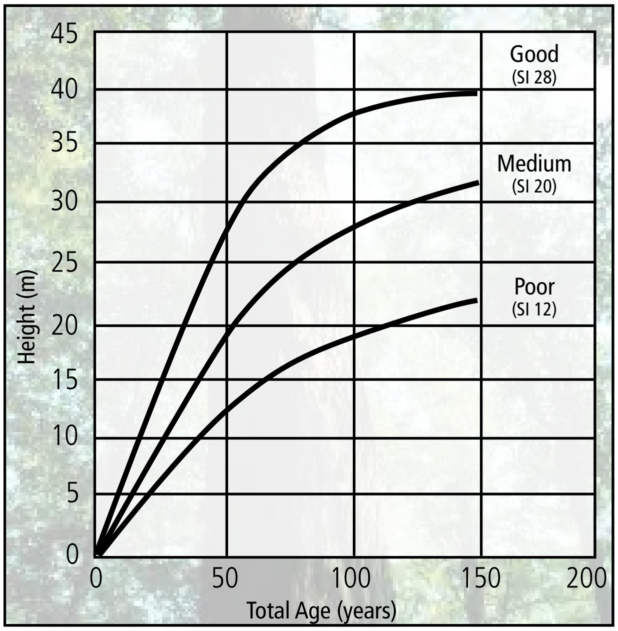


Figure 11: **Sugar Maple Site Index**

There is little an individual producer can do about their existing maple site without spending a great deal of time and money. For example, even if drainage were improved in an existing Sugar Maple stand following flooding, maple response may be limited as there may have already been extensive root dieback. Adjusting drainage, pH and fertility is covered in other sections of the manual. While poor site quality does limit options and expectations, it is still possible to have a sugar bush operation on some lower quality sites.

Adaptation to Disturbance

Sugar Maple is well adapted to a low level of disturbance – primarily individual tree death from disease and decay, and small scale disturbances such as windthrow, localized insect and disease infestations, and localized ice storm or wind damage.

These small scale disturbances tend to create small single tree canopy gaps or medium sized canopy gaps 25–50 m (80–165 ft) in diameter. Sugar Maple has adapted to these site disturbances by becoming shade tolerant; i.e., able to reproduce under partial to almost complete shade.

Maple can also respond to larger scale disturbances such as moderate intensity fires, and severe windstorm events such as tornadoes or severe thunderstorms, ice storms, and clearcuts. These types of larger-scale disturbances open the stand up considerably, releasing existing maple seedlings. In addition, Sugar Maple will usually be joined in these areas by pioneer species such as Trembling Aspen, White Birch and White Pine resulting in mixed stands.

White Birch in maple stand

Without human intervention, maple stands naturally evolve into even-aged stands or uneven-aged stands depending on their disturbance regimes.

Site history will dictate the current biodiversity levels while management actions will influence the future biodiversity of the site.

Stand Structure

Without human intervention, young maple stands naturally evolve into either even-aged stands or uneven-aged stands depending on their disturbance regimes. Even-aged stands arise from more drastic disturbances such as severe fire or severe storms that kill the majority of trees. The new stand that grows up from seed and vegetative reproduction is all the same age. This stand will grow up, naturally thinning itself and eventually become old growth. As the old growth canopy begins to fall apart, new age classes of trees become established in the gaps and grow to reach the canopy. Eventually the stand will be made up of a wide variety of age classes and is now referred to as uneven-aged. Uneven-aged stands persist in nature because hardwoods are shade-tolerant and reproduce and replace themselves under their own canopy. This adaptation allows Sugar Maple stands to persist for many decades, if not centuries.

Many maple stands in Ontario have even-aged characteristics. This is partially a result of fire and storm history, but is also a by product of past management practices. Clear cutting and livestock grazing both create even-aged stands, as does the regeneration of trees on abandoned farmland.

Older even-aged stand

Biodiversity

A healthy woodland or sugar bush has a variety of tree species which can maximize tree growth on variable sites and also provide a range of ecological functions and services including water filtration and infiltration into the soil, provision of wildlife habitat, provision of natural predators of pest species and many others. Income can be realized for maple syrup producers from harvesting non-maple species such as Basswood, Red Oak, Black Cherry, White Ash and other sawlogs. Wood from these species can also be used to fuel for the evaporator.

Site history and management actions will also influence biodiversity in the sugar bush. Site history will dictate the current biodiversity levels while management actions will influence the future biodiversity of the site. Managing for biodiversity to some level may be a mandatory requirement in new national organic certification standards for maple syrup production. Managing for biodiversity may also help buffer against unexpected events such as natural disasters and invasive species. Today, most foresters recommend maintaining some level of biodiversity in the sugar bush.

Diversity in a sugar bush is affected by both human and natural influences. It encompasses all of the life forms and ecological processes within it, including:

- *All species of trees and plants, invertebrate and vertebrate animals, fungi, and microorganisms*
- *The genetic differences among individual species*
- *Complex interactions within the ecosystems that the species are a part of such as nutrient cycling and energy transfer*

The ***Eastern Ontario Model Forest*** *has produced a series of extension notes on biological diversity. For more information please visit* ***www.eomf.ca***

Other Tree Species in the Sugar Bush

Maintaining some non-maple species in your sugar bush, especially on sites where maple may not grow that well, allows for management flexibility in the event of unforeseen disasters in the future. In addition, by keeping the amount of non-maple species to a level that is between 15 and 25% of the total basal area, it is still possible to maintain a productive sugar bush. Table 8, below, lists species associations by site region.

Maintaining a variety of species in any woodland makes good economic and biological sense. Although maple will always be the focus in any sugar bush, there are site types where other tree species will grow more vigorously, producing veneer logs, sawlogs, pulpwood, fuelwood and wildlife habitat.

Use the tree and site characteristics listed in Table 9, page 26, to manage other common species that can be found in your sugar bush. Focus your management efforts for these species on microsites where maple will not thrive.

Basswood saplings in Sugar Maple understory

Table 8: Sugar Maple Dominated Woodlands (see Site Region map page 20)

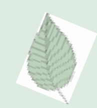
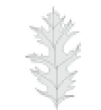
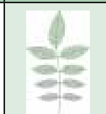
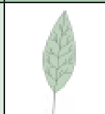
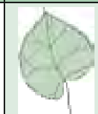
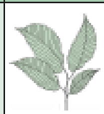
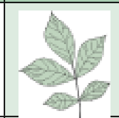
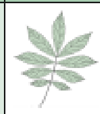
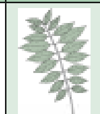
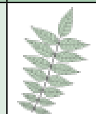
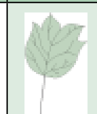
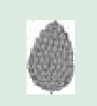
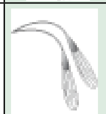
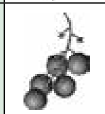
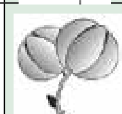
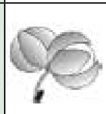
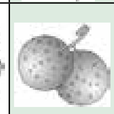
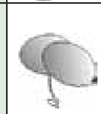
Site Region	Dominant	Common	Less Common	Rare
5E	**Sugar Maple**, American Beech, Hemlock	Ironwood, Yellow Birch, Trembling Aspen, White Birch, Red Oak, White Ash	Black Cherry, White Cedar, White Pine, **Red Maple,** White Spruce, Largetooth Aspen, Basswood	Red Spruce
6E	**Sugar Maple**, American Beech, Hemlock, Basswood	Ironwood, Yellow Birch, Red Oak, White Ash, White Cedar, Bitternut Hickory, Green Ash, Bur Oak	**Black Maple**, Shagbark Hickory, White Elm, White Pine, Largetooth Aspen, Trembling Aspen, White Birch, Black Cherry	Butternut
7E	**Sugar Maple**, American Beech	Basswood, Ironwood, Yellow Birch, Red Oak, White Ash, Green Ash, **Red Maple**	**Black Maple**, Black Walnut, Pin Oak, Shagbark Hickory, Bur Oak, White Oak, Black Cherry	Pignut Hickory, Tulip Tree, Sassafras, Hackberry

Common Shrubs: Leatherwood, Striped Maple, Beaked Hazel, Raspberry, Honeysuckle, Prickly Ash

Common Ferns: Bulblet Fern, Lady Fern, Maidenhair Fern, Oak Fern, Sensitive Fern

Common Herbs: Blue Cohosh, Common Wood Sorrel, False Solomon's Seal, Jack-in-the-pulpit, Nodding Trillium, Sweet Scented Bedstraw, Trout Lily, Wild Ginger, Wild Leeks, Wood Nettle

Table 9: Characteristics of Other Hardwood Trees that Commonly Grow with Sugar Maple

Species	American Beech	Yellow Birch	Red Oak	White Ash	Black Cherry	Bass-wood	White Elm	Shagbark Hickory	Bitternut Hickory	Black Walnut	Butter-nut	Tulip Tree
Leaf												
Seed												
Soil moisture preference	Fresh	Moist	Dry-fresh	Dry-moist	Fresh-moist	Moist	Fresh-moist	Fresh	Fresh	Moist	Fresh	Fresh
Soil nutrient preference	High	High	Low – Medium	High	Low	High	Very High	Undeter-mined	Very High	Very High	Undeter-mined	Undeter-mined
Preferred seedbed	Min/ Humus	Mineral	Mineral	Min/ Humus	Humus	Min/ Humus	Moist Mix	Litter	Litter	Litter	Litter	Humus
Shade tolerance	Very Tolerant	Inter-mediate	In-tolerant	Inter-mediate	In-tolerant	Mid-tolerant	Inter-mediate	Inter-mediate	In-tolerant	In-tolerant	In-tolerant	In-tolerant
Response to release	Medium	Medium	Medium	Medium	Medium	Medium	Moderate	Good	Medium	Medium	Poor – Moderate	Poor – Moderate
Seed crop	2-8 years	1-4 years	3-7 years	3 years	3-4 years	1-2 years	1 year	1-3 years	3-5 years	2-5 years	2-3 years	1 year

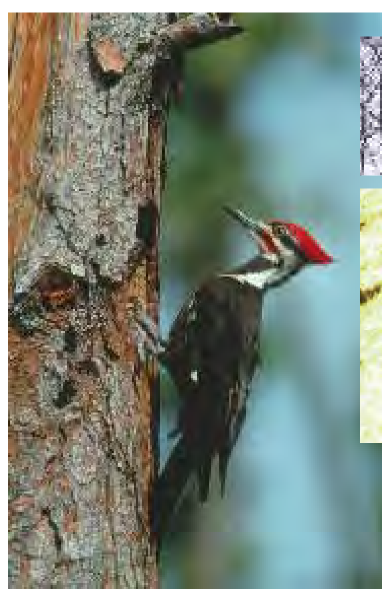
Wildlife in the Sugar Bush

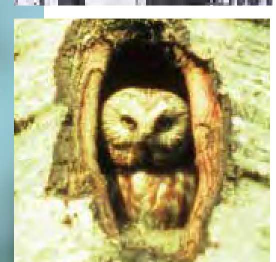
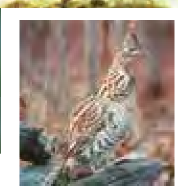
Encouraging wildlife in your sugar bush not only promotes a healthy ecosystem, but it also provides recreational opportunities for hunting as well as wildlife viewing and photography opportunities for visitors to the sugar bush. Keep safety in mind at all times. Remove trees that may become a hazard to people walking in or visiting the sugar bush.

The tolerant hardwood forest of Ontario provides preferred habitat for about 120 species of amphibians, reptiles, birds and mammals. An additional 50 species make occasional use of the tolerant hardwood forest. There are four main habitat features that if maintained in a woodlot, will promote these species.

The four critical habitat features are:

1. **Cavity trees.** 25% of the wildlife living in the sugar bush use cavities for rearing young, roosting, escaping predators or hibernating. Retain at least 6 living cavity trees or trees with the potential to become cavity trees per hectare.
2. **Down-woody debris:** 45% of the wildlife living in the maple forest use logs, branches or stumps on the forest floor for feeding sites, display sites, hiding spots from predators or for hibernation. When harvesting, leave unusable wood in the bush. Also consider girdling or felling and leaving unsaleable stems.



Images at right, clockwise: Pileated Woodpecker; Woodpecker damage; Saw Whet owl in a cavity; Grouse

3. **Mast trees:** 25% of the wildlife living in the maple woodlands consume edible fruits (mast) from trees. Valuable mast producers include Oak, American Beech, Black Cherry, Basswood, Butternut, Hickories and Ironwood. Retain 7–8 good mast producers per hectare (3–4 per acre), preferably with healthy vigorous crowns and > 40 cm (16 in) in diameter. An important issue to consider is that squirrel populations may be enhanced if mast trees are retained. Squirrels often cause severe damage to maple tubing systems.
4. **Conifer cover:** 10% of the wildlife living in the maple woodlands use conifers for cover. Isolated conifers are important for Black-throated Green Warbler and the Blackburnian Warbler and also increase overall songbird diversity.

Paul Wray, Iowa State University, www.forestryimages.org

Gil Wojciech, Polish Forest Research Institute, www.forestryimages.org

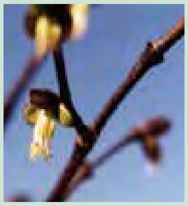
Understory Plants and Shrubs

Understory plants and shrubs are an important part of the forest ecosystem where they help enrich the soil and provide a supply of food and shelter for many wildlife species. In addition, they are often a source of beauty for sugar bush visitors.

Leatherwood is an extremely slow growing shrub with distinctly jointed twigs. Its bark is very pliable and was commonly used by Aboriginal people for weaving baskets and rope.

Jack-in-the-Pulpit is a long-lived plant capable of surviving for up to 100 years. Although its leaves can irritate or blister the skin when handled roughly, its root was cooked and eaten as a vegetable by Aboriginal people.

Sensitive Fern gets its name from the fact that it is intolerant of frost and will often die back as soon as the night time temperature dips below zero. It prefers wetter microsites where it can form thick groupings.



Today our understanding of how a maple woodlot functions has changed and many sugar bush managers are realizing the benefits of a more diverse woodlot.

Management Considerations for Biodiversity

In the past, sugar bush management techniques recommended the removal of all non-maple species in an attempt to maximize the number of taps per hectare (acre). Today however, our understanding of how a maple woodlot functions has changed and many sugar bush managers are realizing the benefits of a more diverse woodlot. Consider the following when making decisions regarding the biodiversity of your sugar bush:

- Income can be realized from harvesting sawlogs of other tree species such as Basswood, Red Oak and Black Cherry. Retaining some valuable tree species in the sugar bush until they reach at least 50 cm (20 in) dbh can prove very profitable.
- In many sugar bushes in Ontario, it is possible to retain as much as 25% of the trees in non-maple species without seriously impacting sap production per hectare (acre).
- On many sites, Sugar Maple is a tree that tends to dominate over other species. On these sites maple will tend to reproduce, grow and eventually move into the overstory naturally without the need for intensive management.
- On some sites which are not as suitable to the growth of Sugar Maple, other species will tend to naturally dominate. On these sites, it may require considerable management effort to keep the stand in maple over the long term.
- Greater diversity in surrounding woodlands may be maintained to compensate for lower tree species diversity in the sugar bush.
- Shading from Balsam Fir, Hemlock, and White Spruce keep temperatures low during the spring, decreasing sap flow and thawing of sap collection systems in the early part of the season. Shading may be a benefit near the end of the season however, when high daytime temperatures can degrade sap quality.
- Maintain conifers along the edge for protection from wind.
- Approximately 120 to 200 taps per hectare (50–80 taps per acre) are necessary for a sugar bush to be economically viable. A large proportion of non-maple tree species (over 25%) in a sugar bush may significantly reduce the potential income per hectare (acre).
- Matching species to site within the sugar bush involves allowing small pockets of other-species trees to remain on sites that are not ideal for Sugar Maple.
- Numerous understory plants, soil organisms, animals, birds, fungi, and decaying organic matter contribute to the biodiversity of the site.
- A range of ages and sizes of maple trees, genetic diversity within the species, and natural hybridization between Sugar, Black, and Red Maple contribute to biodiversity within the maple species.
- Retaining a number of snags may enhance the biodiversity of the sugar bush. Snags provide shelter and food for several types of birds, which in turn help to control insect populations within the sugar bush. (Do not keep any trees that may be a danger to people or a source of disease to other trees).
- *Mycorrhizae* are a group of naturally occurring, beneficial fungi that form associations with tree roots. They enhance the uptake of certain nutrients, particularly phosphorus. Leaving a number of large tree trunks to decompose on the forest floor helps to promote mycorrhizal growth and their incorporation into the soil. The decaying woody material and the mycorrhizae contribute to biodiversity and health of the sugar bush.

Sugar Bush Management Techniques

Your sugar bush like the rest of your woodlands is a complex association of plants, animals and microorganisms all interacting among themselves and with the environment in which they live. As a result, your sugar bush is constantly changing or evolving. Trees grow, reproduce and eventually die through the influence of insects, disease, human activities and climatic conditions. Management is our attempt to control and shape these influences toward a desired outcome. We manage our woodlands to keep them healthy and to provide us with the products and benefits we desire. These can be high value sawlogs, suitable wildlife habitat, recreational trails and paths, or for the sugar bush operator, an annual crop of sweet sap.

While you don't need to manage your sugar bush to produce maple sap, management will help ensure that your sugar bush is capable of supporting a maple operation on a continual basis. Good management techniques can also enhance the commercial viability of your sugar bush by enhancing tree health, maintaining the optimum number of taps, and minimizing potential problems before they become serious.

Managing the sugar bush requires time and effort, and in some cases, money. Many producers recognize that the potential benefits from following good management practices outweigh the drawbacks, especially over the long term. They enjoy working in the sugar bush and seeing the positive results of their efforts. Some producers however, find it hard to justify management activities if an immediate monetary return is not realized.

While you don't need to manage your sugar bush to produce maple sap, management will help ensure that your sugar bush is capable of supporting a maple operation on a continuous basis.

Benefits of Management

The investment of time and money in sugar bush management today can have significant long-term benefits for the maple producer in the future. The well-managed sugar bush can be both productive and healthy. In addition, the producer may profit from a number of other secondary benefits like a periodic supply of fuelwood and timber. When asked what benefits they have received from managing their sugar bushes here is what two Ontario producers had to say:

"I enjoy working in my woodlot, it looks great and it has been fantastic to see the improvement."

Over the years, this producer has sold firewood and sawlogs, and is now tapping new trees in the thinned sections. He estimates that he has added about 10% more taps to his operation, due to his management efforts.

Fuelwood harvested from the sugar bush at Gunnewick farm in eastern Ontario

"For me, the economic benefits are secondary – they will come later if you take care of your bush. It is a pleasure seeing the young saplings coming in. They are fast growing."

This producer is promoting the growth of new trees to replace some of the older over-mature ones. His main goal is to improve the health of his sugar bush. Over the years he has fenced out cattle, reduced the number of taps on each tree, and switched over to the health spile.

Robinson sugar camp in western Ontario

Working in the sugar bush

Tree growth, especially diameter growth, is influenced by several interrelated factors such as:

- Tree age
- Genetic makeup
- Site type
- Seasonal weather patterns
- Tree health
- Stand density

Variations in any of these factors will influence how quickly a tree grows and ultimately, how large it gets. Management actions which enhance site conditions or stand density, as well as those that help reduce or offset stress can improve sugar bush productivity.

Increased Growth Rate

A young tree in a well managed sugar bush will grow in diameter considerably more quickly than a young tree in a dense, unmanaged sugar bush on a similar site. This means that it will reach a tappable size and increase in number of potential taps sooner. In the example below, the tree disc on the left comes from a well-managed sugar bush and is 6.3 cm (2.5 in) larger and 23 years younger than the tree disc on the right which came from an unmanaged sugar bush.

Diameter growth of immature Sugar Maple in managed and unmanaged sugar bushes

Improved Sap Yield and Sweetness

Over time, harvesting trees that have a lower relative sap sweetness can improve the overall productivity of your sugar bush. For additional information on sap sweetness and its impact on sugar bush productivity, see Appendix B, page 123.

Producer using a sap refractometer to test for sap sweetness

Improved Site Conditions

Enhancing the drainage in wetter areas of your sugar bush can improve site conditions which affect the growth rate of Sugar Maple. Drainage may also make the site less suitable to Red Maple and Silver Maple.

Factors Influencing How to Manage a Sugar Bush

There are two interrelated factors which govern how your sugar bush should be managed for improved health and productivity. These are:

1) Your objectives for the future of the sugar bush

Setting realistic and achievable objectives is an important step in the sugar bush management process. The management techniques described in this manual are geared at the following three main objectives:

- Maintaining health and vigour
- Maintaining appropriate productivity
- Promoting the next generation of trees

2) The structure of your sugar bush (its size, age, health and inventory characteristics)

Improvements in growing conditions can be made by manipulating the structure of the sugar bush – this may involve thinning to free up resources for the remaining trees, promoting regeneration, improving drainage within the sugar bush, or reducing the damaging effects of insect and disease.

Management objectives are introduced later in this manual (see Parts of a Management Plan). Some of the structural characteristics important for determining management techniques are introduced here.

Sugar Bush Size

The size of your sugar bush (Table 10) can have an impact on the management actions you choose to implement. In medium- and especially in larger-sized sugar bushes, there is usually enough area to maintain a productive operation and at the same time manage for adequate levels of regeneration. It is possible to harvest trees without significantly impacting sugar bush productivity.

For the small-scale operator however, it is sometimes hard to maintain an adequate level of regeneration without reducing the overall productivity of the sugar bush. This is especially true for smaller sugar bushes with a high proportion of large, over-mature maples. In these sugar bushes, thinning to a recommended level will inevitably result in the loss of tappable trees. As a result, maple producers who are attempting to manage smaller sugar bushes may find that there are some practical limitations in the application of the techniques listed in this publication. Thinning to promote regeneration as well as the growth of smaller untappable trees is still advisable in smaller sugar bushes. The operator of the small-sized sugar bush may choose to cut fewer trees and stage the harvest out over a number of years to help minimize any reduction in sap yield.

The size of your sugar bush may have an impact on the management actions you choose to implement.

Table 10: **Management Implications Based on Sugar Bush Size**

Sugar Bush Size	Number of Taps	Management Implications
Small	< 1000	• Often more difficult to maintain sap productivity and, at the same time, promote adequate regeneration • Thinning to recommended levels may result in tap loss.
Medium	1000 to 6000	• Usually able to apply management recommendations without long-term impacts on productivity • Thinning to recommended levels may result in some short-term productivity loss.
Large	> 6000	• Usually able to apply management recommendations without long-term impacts on productivity • Thinning to recommended levels can usually be done with minor impacts on productivity. • Numerous management options available • Full economies of scale

Past Management Activity

The past management history of your sugar bush will directly affect the future management options for it. If it has been well managed, you will have more options and management activities will have benefits for both stand health and productivity. If it has not been managed or if it has been poorly managed, your options are going to be more limited. Some examples of past management practices which have negatively affected the sugar bush include:

1. Cluster tapping
2. Logging damage
3. Cattle in sugar bush
4. Severe rutting in sugar bush

1

2

3

4

- **Poor tapping practices** – how your trees were tapped in the past will influence tree health and ultimately tree productivity in the future. Over tapping or cluster tapping can reduce productivity especially in slower growing trees.
- **Past harvesting practices** – producers with mature overstocked sugar bushes will not see an immediate improvement in productivity as a result of management actions. In many cases, they may even experience a significant loss of productivity in the short term due to a reduction in taps. In these sugar bushes, management activities are necessary to promote regeneration and thus future sap yields in the long term. Poor harvesting practices can have a significant impact on tree health as well. Rutting and skidding damage from previous harvests can have a negative long-term impact on the productivity of a sugar bush.
- **Grazing** – in the past, many producers commonly grazed cattle in their sugar bushes. This practice has been shown to have a negative impact on site and tree health and is strongly discouraged.
- **Road Construction** – a poorly designed and built network of roads can unnecessarily reduce the area of the sugar bush available for tapping. Other significant impacts include disrupting or altering natural drainage patterns.

Stand Age

One of the most important stand characteristics influencing management technique is the age distribution of the trees in the sugar bush. Foresters like to classify the distribution of ages in a stand into one of two categories – even-aged stands or uneven-aged stands. Are the trees in your sugar bush close in age or are there a wide number of ages present? The techniques used to manage them are different.

Uneven-aged and Even-aged Sugar Bushes

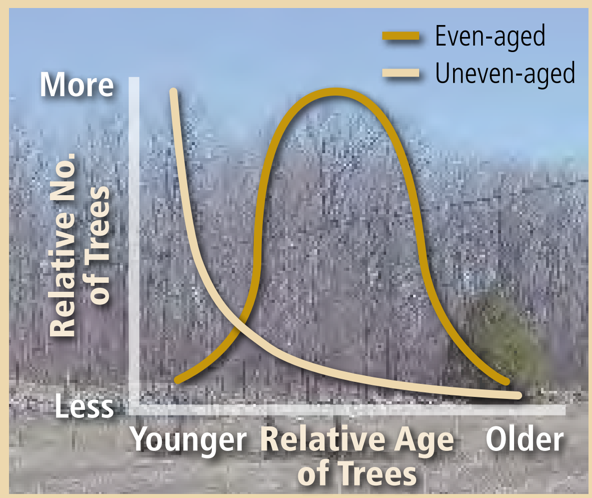


Figure 12: The age structure of the even-aged and uneven-aged sugar bush is quite different when plotted on a graph. For the **uneven-aged** distribution, note how there are many more younger trees than there are older ones. For the **even-aged** distribution of trees, note how most of the trees are about the same age. When plotted on a similar graph, your sugar bush may look like one of these distributions or it may be something in-between.

Young, dense, uneven-aged Sugar Maple stand

It is possible to have a productive and sustainable sugar bush regardless of its age structure. However, if you are wondering whether even-aged or uneven-aged management might be more appropriate for your sugar bush keep the following points in mind:

- Your choice will be dictated by what you have now – it is not possible to convert from even-aged to uneven-aged in the span of one cutting cycle. It can take many decades to promote regeneration and tree replacement.
- Uneven-aged stand structures in maple dominated woodlands are usually preferred by foresters but may take considerable time to achieve if the stand is initially even-aged.
- It is necessary to promote regeneration for both age structures – failure to do so will eventually result in tap loss and lower sugar bush productivity.
- Mature, even-aged stands will tend to have higher number of taps per hectare (acre) but over time, as trees die, this number will drop off.
- There are challenges to managing both types of stands – in an uneven-aged stand, it is important to account for different age classes in the decision making process. In even-aged stands, careful planning is required to ensure regeneration for long-term sap production.
- Sugar bushes which are tapped and not properly managed will eventually convert to an even-aged stand structure.

Without promoting regeneration, an even-aged sugar bush may become less productive as the trees eventually begin to decline and die over time.

How does sugar bush age structure affect the number of taps over time?

In managed uneven-aged sugar bushes, the number of taps fluctuate slightly but remains relatively constant because the growth of younger trees is promoted. New trees grow to replace mature ones. This type of sugar bush would generally have fewer taps per hectare (acre) than a mature, even-aged operation but will have a relatively continuous level of productivity.

While even-aged sugar bushes may have more taps per hectare (acre), it is only a temporary phenomenon unless regeneration is encouraged to offset tap loss. Without promoting regeneration, an even-aged sugar bush may become less productive as the trees eventually begin to decline and die over time. In some sugar bushes, especially in those where there is little advanced maple regeneration, it can take many decades before this loss of taps is overcome and the operation becomes productive again.

Even-aged Sugar Maple stand

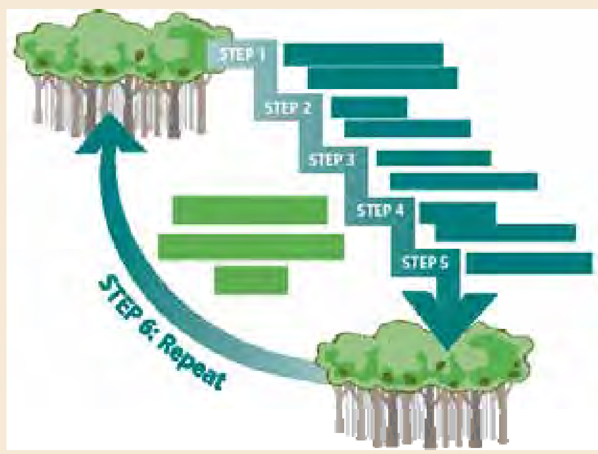
Sugar bush management is a planned set of activities which are intended to maintain or improve sugar bush health and productivity.

Sugar Bush Management Activities

Although some people think of 'management' as logging or harvesting the woodlot, it is much more than this. Good management practices involve a number of related activities which may or may not include harvesting. Sugar bush management is a planned set of activities which are intended to maintain or improve sugar bush health and productivity. These include:

- **Planning** – good sugar bush management seldom just happens. Improving both stand productivity and health requires an understanding of how the sugar bush functions and how it is influenced by your activities within it. (see p 35)
- **Inventory** – knowing what you have and how well it is doing is the first step in determining what is recommended for the sugar bush. Your inventory results can be compared to known standards to give you an indication of the health and productivity of your sugar bush. (see p 40)
- **Prescription Development** – using inventory information to determine management recommendations which will be applied to a sugar bush. (see p 49)
- **Marking** – applying the prescription to the sugar bush. Marking identifies which trees to cut and which ones to leave. (see p 50)
- **Thinning** – harvesting activities within the sugar bush. Good harvesting practices minimize damage to the remaining trees and set the stage for increased growth and productivity. (see p 53)
- **Trail and Road Establishment** – laying out and building a trail and road infrastructure. Roads and trails often disrupt roots and may change drainage patterns; minimizing negative impacts is important for long-term health.
- **Tapping** – good tapping practices minimize any negative impacts on tree health and allow the sugar bush to be productive year after year. (see p 78)
- **Sap Collection** – tubing systems for sap collection should be designed and installed to minimize damage to maple and non-maple crop trees. Sap collection activities should be carried out with minimal damage to the site. (see p 83)
- **Monitoring** – keeping good records of what is happening in your sugar bush. Many sugar bush owners record what they have done and what they have seen in an annual report. Observations on tree health, insects, weather as well as other impacts can be used to assess whether your sugar bush is changing for the better or the worse.

Figure 13: **The Management Cycle**



Think of your approach to management as a series of steps which will be repeated over time. Initial efforts are focused around planning and inventory. Later on, depending on what you want to do and the inventory, you may decide to thin your woodlot. This may be done in one operation or carried out over a number of years. Some steps like monitoring are ongoing and should be carried out at various times each year throughout the term of the plan.

Preparing a Management Plan for the Sugar Bush

Planning is the first step toward achieving your goals. A sugar bush management plan is a written document that details how you are going to do this. It is a guide or road map which lays out what you want to do, and how you plan to do it over the next few years.

The Benefits of Management Planning

Management planning has many benefits. It can:

- Guide sugar bush operations over the term of the plan. It is a tool that can help save time and money by clearly laying out what needs to be done in the sugar bush. By planning for an extended number of years you can assess the cumulative impacts of your management actions as you progress toward improving the overall health and productivity of your sugar bush.
- Act as the foundation for a business plan which summarizes the financial objectives of your operation. A sound business strategy can help you when it comes to tax planning as well as securing additional capital from a lending institution. It also demonstrates a long-term commitment to the proper management of your sugar bush.
- Help you qualify for programs such as the Managed Forest Tax Incentive Program and the Seal of Quality Program. It is also a necessary component of forest certification systems and some organic certification programs as well.
- Be a very useful reference when planning the transfer of the sugar bush between generations.
- Provide a means of avoiding the loss of important information. Often much of the historical records of a sugar bush resides in the memory of a single individual. If this knowledge and experience is not written down, it will be lost for future generations.

A forestry consultant with experience in maple management can help you develop your management plan. The detail and intensity of your plan will be dependent upon a number of factors, including:

- **Your desired level of involvement** – there is no sense developing a plan that is so complex that it is unachievable. Keep it realistic and remember that the plan is only one step in the management process; eventually you have to follow through on the activities listed in order to achieve your goals.
- **The size of your operation** – a sugar bush that is 120 hectares (300 acres) in size will warrant a plan that is more comprehensive than one that is 4 hectares (10 acres).
- **The number of stands you identify** – a stand is an area of woodland that is distinctly different (species, sizes, age etc.) than another area. If your sugar bush is quite variable and has a number of different stands, your plan will need to reflect this.

There may be other woodlands on your property in addition to the sugar bush. Ideally, your plan should include information on these stands. The objectives, management activities, and intensity of management for these areas are dependent on the type of woodland and your intended usage of it. This is particularly important to a maple operation if there are plans to expand the sugar bush into other untapped parts of your property. Also, these adjoining woodlands may be able to provide benefits which are unachievable in the sugar bush.

A forestry consultant with experience in maple management can help you develop your management plan.

Your plan is specific to your woodland area and includes information important to your operation.

Parts of the Management Plan

Your plan is specific to your woodland area and includes information important to your operation. Most plans are organized into a number of distinct sections, some of which are listed below. Depending on your own needs and wishes, you may have additional sections in your plan.

Common sections of a management plan

- **Term of plan** – number of years plan is to be active
- **General property description** – size of property, other land uses, legal description
- **Detailed maps** – showing the property, stand and compartment boundaries
- **History** – natural events and human activity
- **Description of long-term objectives** – what you hope to achieve in the long term
- **Site information** – details on landform, soils and drainage
- **Sugar bush inventory** – often listed by stand or compartment
- **Description of short-term objectives** (your Operating Plan) – what you intend to do over the next few years
- **List of contacts** and relevant **reference material**

Term of Plan

In most cases, a management plan covers a 10 to 20 year time frame. Having a relatively long term for the plan is beneficial because it eliminates the need to prepare a new plan every few years. It also lets you list planned outcomes of your management actions. Management is a long-term process and desired goals often take years to reach.

Long-term Objectives

These are your desired outcomes from management or what you want your woodland area to be like at the end of the plan. Long-term objectives, often called goals, are general statements describing what you are managing your property for. Most landowners have more than one long-term objective for their property. Some examples of long-term objectives could include any, or all of the following:

- Increasing the average number of taps per hectare (taps per acre) – *"I want to increase the number of taps by promoting the growth of younger trees."*
- Improving the health of the sugar bush – *"At the end of my plan, I want my sugar bush to be healthier than it is now."*
- Producing maple syrup – *"I want to produce maple sap over the term of my plan."*
- Generating some additional revenue through the sale of timber and fuelwood – *"I want to sell some of the logs I harvest through thinning."*
- Promoting the growth of small trees – *"I want my small maples to grow at their best rate."*
- Establishing an orchard – *"I want to have a well established maple orchard in my unused field in 20 years."*
- Promoting wildlife – *"I want to promote nesting habitat for red-shouldered hawk."*
- Increasing sap sweetness – *"My sugar bush has an average sap sweetness of 2; I want to increase this by the end of the plan."*

Short-term Objectives

While long-term objectives tell us where you want your woodlot to be at the end of the plan, they don't tell us what you will do to get it there. For example, increasing sap sweetness is a planned outcome of management which will not necessarily happen unless you use sap sweetness measurements as a factor in the selection of crop trees. Short-term objectives, like selecting sweeter trees over less sweet ones, describe specific activities you plan to do in your sugar bush. Short-term objectives are realistic, achievable and measurable management actions that support your long-term objectives. They might include:

- Thin to promote growth – *"I plan to thin Compartment 1 over the next two winters."*
- Hire a tree marker to mark a stand – *"I will hire a certified tree marker this summer to mark my Ash, Pine and Maple stand for thinning."*
- Build a road to improve access – *"Compartment 7 has 200 potential taps but is currently inaccessible. I will extend my main sugar bush road over the next 5 years."*
- Monitor and record observations on my sugar bush – *"I will create a log book for my operation."*
- Reduce the number of taps in ice-damaged section of sugar bush – *"I will follow the Conservative Tapping Guideline on my severely damaged trees."*
- Transplant 200 maple saplings into an unused field – *"I will transplant 50 saplings each year for the next 4 years."*
- Release Sugar Maple saplings - *"I will identify and release maple seedlings with good form in Compartment 5."*
- Install new tubing – *"I will install a new tubing system in my main sugar bush."*

Obviously it is impractical to list all the activities you plan to carry out over the entire period of your plan. For this reason, your short-term objectives are best listed in a separate section of your plan – often called the Operating Plan (see Page 44). This section covers a much shorter term usually around five years in length and lists the activities you intend on carrying out to help achieve your long-term objectives. If your plan covered a 20-year timeframe for example, it is recommended that you develop four 5-year operating plans.

Short-term objectives are realistic, achievable and measurable management actions that support your long-term objectives.

Sugar Bush Maps

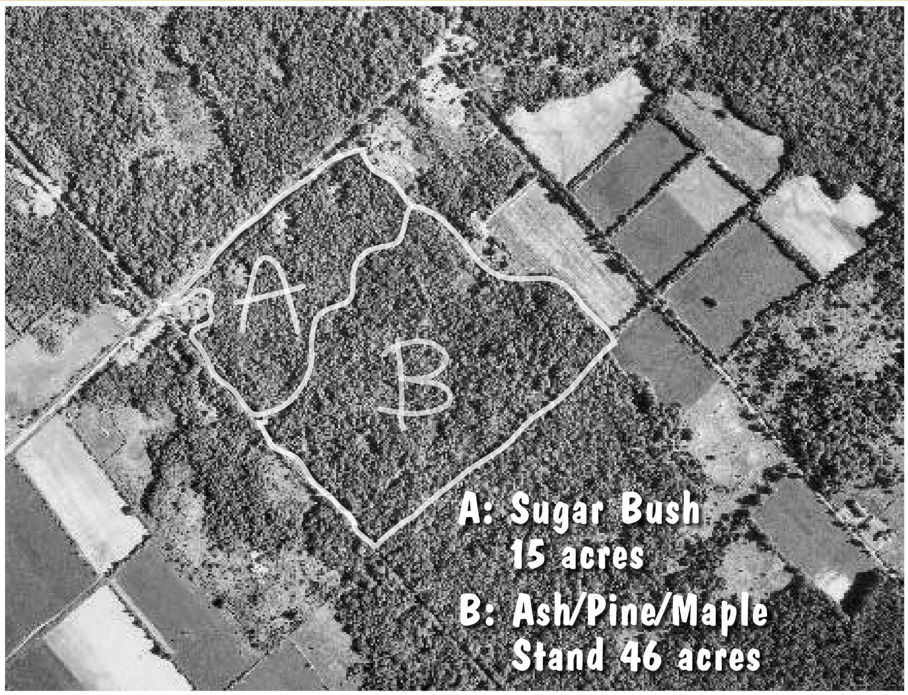


Figure 14: **Aerial View**

Including non-maple stands in your management plan is a good idea, especially if your long-term objectives include expanding your existing operation. In this example, the proper management of the Ash, Pine, Maple stand could lead to an eventual increase in the size of the Sugar Bush.

Breaking the sugar bush up into smaller compartments makes the management process more straightforward. It is often easier to focus on one or two sections of the sugar bush at a time rather than the whole thing all at once.

Sugar Bush Maps

Maps are very useful management tools. They lay out property boundaries, stands and compartments. They also identify physical features necessary to orient yourself when you are out in your woodland area.

Aerial photographs can be very helpful in preparing a map of your property. They allow the property and sugar bush to be viewed in relation to the surrounding landscape and help establish scale and proper location of different components. Aerial photography can be ordered online through the Ontario Ministry of Natural Resources website (www.mnr.gov.ca).

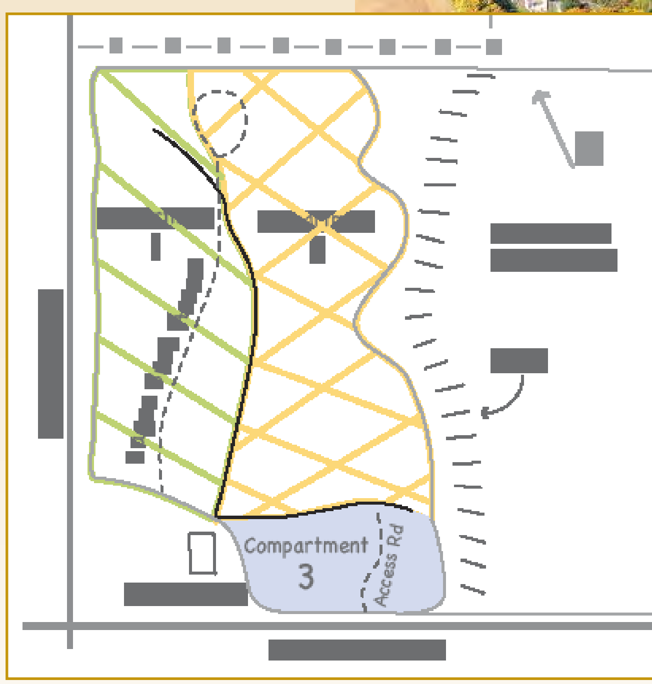
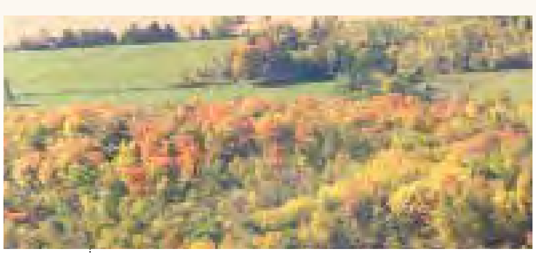


Figure 15: **Sugar Bush Map Based on Aerial View**

A stand is an area of woodland with similar tree species, sizes and age structure. A stand may be further subdivided into compartments based on physical characteristics like roads, property boundaries and tubing infrastructure. In this case, the sugar bush makes up the stand, which has been further divided into three compartments.



5 Steps to Developing a Management Plan

Management planning need not be a difficult process. If you are employing the services of an experienced forest consultant, he or she will be quite knowledgeable in the planning process. If you are attempting to do all or some of it yourself, it is best to break the planning process up into a number of steps. Begin by collecting the information needed to support the plan – much of this will become part of the plan. Work on each step separately and use published books, extension notes and web sites as reference material to validate your decisions.

Step 1: Information Gathering

Collect the supplemental information necessary to develop your plan. This should include aerial photographs, topographical maps, property survey maps, management planning references and specific property information like lot and concession.

Step 2: Summarize the property, history and other general information into individual sections.

Much of this information will not change much over the term of the plan. At this stage you might want to develop a detailed property map showing all the general features associated with the area. This could include roads, wetlands, open fields and property boundaries.

Step 3: Determine your long-term objectives for the property and your sugar bush operation.

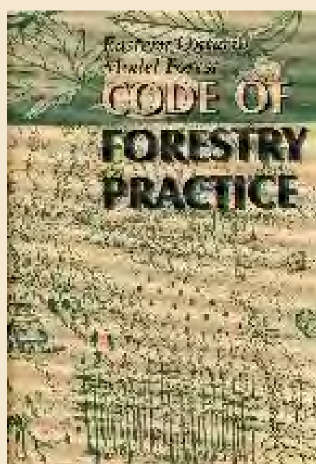
Do you plan to keep the property and possibly hand it down to your children? Do you want to extract other products from the woodlot? How big do you see your operation being at the end of the plan? At a minimum, a fundamental long-term objective should be to improve or maintain the health and productivity of your sugar bush.

Step 4: Develop the Sugar Bush Inventory

You can't make informed management decisions without first knowing what the status of your woodland area is. The sugar bush inventory is used to compare what you have to what is recommended. Inventory results are usually summarized in a stand by stand (or compartment by compartment) description so it is recommended that a stand or compartment map be developed to support your findings. Specific boundaries can usually be located on an aerial photograph of your property. Each compartment should be clearly labeled and its area should be estimated. More information on the sugar bush inventory is provided in the next section.

Step 5: List your short-term objectives in an Operating Plan

Your operating plan lists what 'on the ground' activities you are planning to do over the next few years. More information on developing an operating plan is provided on page 44.



Additional detailed material on developing a management plan can be found in the Eastern Ontario Model Forest's ***Code of Forestry Practice***

Available at ***www.eomf.on.ca*** *.*
In addition, many resource management organizations offer workshops or seminars on management planning.

Your operating plan lists what 'on the ground' activities you are planning to do over the next few years.

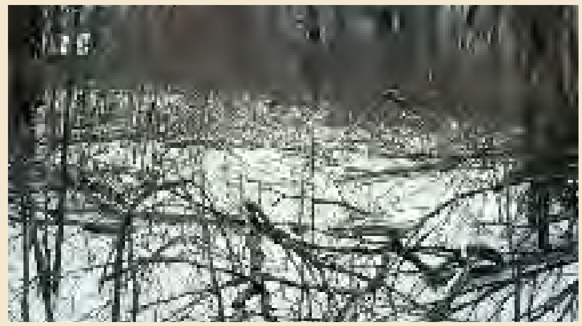
Allow for Change

Your plan helps you set up a process for achieving your goals but what do you do if something unforeseen happens? Changes in markets, weather events, management techniques as well as other factors may affect your ability to follow through on your intentions.

Sugar bush management requires a long-term commitment to improving your woodlot. Over the years, it is possible that something unpredictable will happen that will require you to change your plan. It is important to allow for flexibility in your management actions.

Think of your plan as a working document where any new developments or changes are incorporated into it. Keep your plan up-to-date by adjusting it as necessary. Most changes are minor and don't require much of a correction in your management actions. Some events however, can have a significant impact on your sugar bush requiring a change in your planned management activities.

Catastrophic changes like a wind or ice storm can dramatically alter the composition or age structure of your sugar bush and may require a complete revision of the plan. Other events like prolonged periods of dry weather and/or insect infestations may require that you defer a planned harvest or alter tapping practices



Fallen branches and bent saplings after a severe ice storm.

The Sugar Bush Inventory

An inventory is a 'snapshot' of your sugar bush at a specific point in time. It provides some of the important information needed to make informed management decisions. An inventory can also provide information on the overall quality of the site on which the maple resource is growing. Is it a productive site for maple growth or is it an unproductive site? The answer to these questions has a direct impact on the long-term potential of the woodland to sustain sap production.

Each stand needs to be catalogued separately and if you have further subdivided your stands into compartments you may wish to keep these separate as well. The scope and detail of the inventory will in part depend on your management objectives. Conduct the inventory with these objectives in mind and collect the information necessary to make informed decisions.

An inventory of your sugar bush will generally provide some of the information contained in the following table.

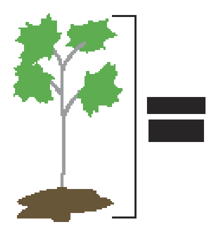
Table 11: Inventory Collected from a Sugar Bush

Information Type	Comments
Tree species	• The relative number of trees of different species. • Usually expressed as a percentage: 70% maple, 20% beech, 8% hemlock, 2% other species
Tree diameters	• Generally for trees above 10 cm (4 inches). • Used to generate a diameter distribution showing the relative number of large and small trees. • Will also provide an indication of the total number of taps: 30 single-tap trees, 100 two-tap trees, 26 three-tap trees
Tree Health	• Each tree measured is assessed and the general health rating is recorded (for more information see 42) • Are the trees growing well or are they declining in health?
Number of trees per hectare (acre)	• The number of trees per hectare is a measure of tree density. Density, in turn, can be used with the diameter distribution to determine if there are too few or too many trees for optimal growth.
Average Tree Height	• Tree heights provide a measure of site quality – trees tend to grow taller on better sites.
Site or stand problems	• Intermittent flooding, invasive species, animal and bird damage can all impact general stand health.
Regeneration	• The abundance and type of regeneration determines future forest composition.
Basal Area	• Basal Area (BA) provides a measure of stand stocking. Are there too many or too few trees growing in your woodland? It is useful when determining if thinning is warranted. For additional information on Basal Area see Appendix D, p 127.
Site Quality	• A trees growth potential is in part determined by the quality of the site. Different sites support the growth of different species – will maple grow well on your site or will it be out-competed by other species. For more information see p 22.

A viable Sugar Maple seedling is greater than 50 cm (20") in height and less than 2.5 cm (1") in diameter.

Assessing regeneration in your sugar bush inventory

When you look at the seedlings growing on the forest floor, you are seeing the future of your sugar bush. Shade tolerant species like Sugar Maple should out number all other species – if they do not, then it will be more difficult to keep the forest in maple. Some studies have shown that maple regeneration is insufficient if there are less than 5000 seedlings per ha (1 seedling every 2 square metres). Ideally, this regeneration would be distributed uniformly throughout the sugar bush. If your sugar bush does not have adequate maple regeneration in the understory or if it is all concentrated in one or two areas, you will have a difficult time keeping it in maple unless you promote maple regeneration and dissuade unwanted species like aspen, birch, beech and ironwood from becoming established.



A viable Sugar Maple seedling is greater than 50 cm (20") in height and less than 2.5 cm (1") in diameter.

As you conduct your inventory, one of the most important things you need to do is to assess the health status of each and every tree you measure.

Tips for Assessing Maple Regeneration

- Count seedlings which are greater than 50 cm (20") in height – they stand a much better chance of survival after harvesting.
- Count the regeneration in 10 by 10 meter plots scattered throughout your sugar bush – a 10x10 m plot is 1/100th of a hectare. Multiply the number counted by 100 to get the number per hectare for the plot.
- Count all species and compare the results – maple should outnumber all other species.
- Check other areas to ensure that seedlings are distributed throughout the sugar bush.
- Look for signs of browse – deer can have a major impact on seedling growth and survival.

What is the future of this tree?

As you conduct your inventory, one of the most important things you need to do is to assess the health status of each and every tree you measure. Is it healthy? Is it declining? Or is it somewhere in between? Another way of looking at it is to ask the question: what is the future of this tree? If you were to come back in 10 or 20 years or during the next inventory, what kind of condition would you expect that tree to be in? Will it be part of my operation in the future or will it be taking up space that could be better occupied by a healthier (but younger) tree?

Assessing Tree and Stand Health

Basically, what you are trying to do is get an idea of the general health of each tree and of the sugar bush as a whole. This information is just as important as some of the other easier-to-measure characteristics like diameters. It needs to factor into your management decision making process. Foresters generally use the terms Acceptable Growing Stock or Unacceptable Growing Stock (AGS and UGS for short).

It is relatively easy to make assumptions about the future of the stand by looking at the summary of the tree health assessment. If most of your larger trees are in poor health and declining, you can probably expect to see a decrease in the number of taps over time. Assessing health is just as important for smaller trees as well because if most of them are over-topped, crowded or exhibit poor form, it is unlikely that they will grow to replace the larger trees once they are gone. In this example, the long-term future of this woodland as a sugar bush is in question and intervention aimed at improving the health and growth of the younger trees is necessary to turn it around. If however, your sugar bush has only a small percentage of UGS trees (remember, there are always some, even in the best woodlots) you can expect it to remain healthy and productive, at least for the next 10 to 20 years barring major disturbance.

Tips for Assessing Tree Health

- **Look at the leaves of the tree** – are they healthy looking and the appropriate size? Are they an unusual colour for the season (early to late summer) or do they show signs of mottling or yellowing. Are there many dead or dying leaves? See page 93 for a chart of defining symptoms.
- **Look at the branches** – is the crown healthy and full looking or are there obvious signs of decline or damage? Are the smaller branches fully leaved or has there been some dieback? Is it a large crown

appropriately sized to the tree or is it a small compact crown?

- **Look at the trunk** – is it split or damaged in any way? Are there obvious signs of decay, fungi or insect damage? On smaller trees, does the bark look healthy, smooth and tight or does it resemble the bark of a mature tree? Are the tap holes closing in one to three years or are they still open after four?
- **Look at the ground** – are the roots visible or damaged? Are there mushrooms around the base of the tree? Are there any hollows or wounds at the base of the tree?

One of the more challenging decisions faced by the sugar bush operator is determining how much of the woodlot to inventory – should each tree be measured or will a sample of trees be acceptable? The answer to this question depends on the reason why you are inventorying your sugar bush in the first place. If you are planning to conduct thinning operations then measuring each and every tree is not necessary. Management decisions as to the numbers, species and sizes of trees to be harvested can be made from a representative sample of trees measured in the sugar bush.

As a syrup producer however, it is important for you from an operational perspective to measure every tappable maple (trees greater than 25 cm or 10 in) in the sugar bush. Knowing the number and diameters of the tappable maples especially on a compartment by compartment basis, will help you organize your yearly tapping operation. It is also a good idea to measure maples which are in the 1.5–25 cm (4 to 10 in) size class; knowing how many of these trees you have, and roughly where they are located in the sugar bush will give you an indication of future management options and needs.

Keep in mind that your goal is to improve your sugar bush by bringing its structure (number of trees, size and species distribution) closer to what is considered best or ideal for your site. By comparing what you have now, to what is recommended, you can develop a set of guidelines for the number, type and sizes of trees that should be removed in order to achieve this goal. These guidelines are called a prescription and are a list of instructions recommended for the sugar bush. Usually this is done by marking trees for removal as well as crop trees which will be left to grow.

Harvesting Decisions

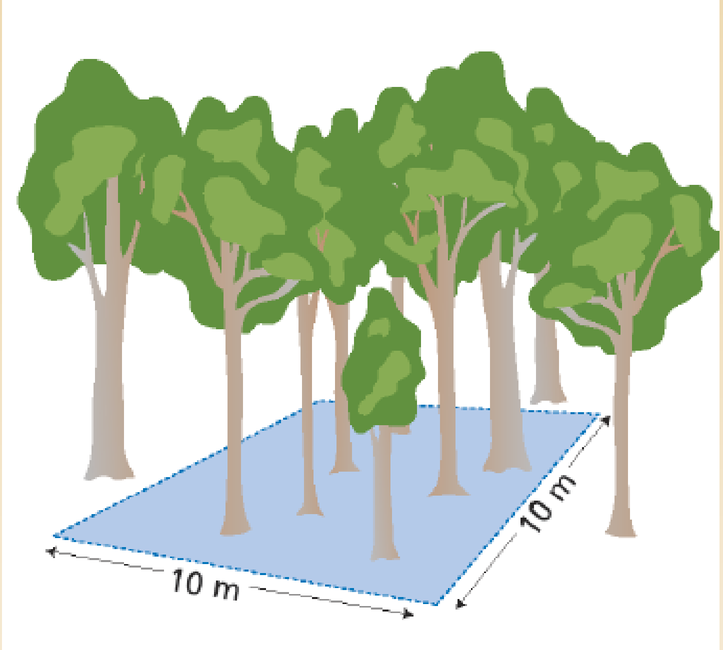


Figure 16: Harvesting decisions can be made by looking at a sample of inventoried trees collected using either **fixed area plots** or with a **prism**. For the landowner, the use of fixed area plots is perhaps the most appropriate method. A forest consultant will probably use a prism, but may use either method.

Fixed area plots have an area that is dependent on their length and width. Measuring all the trees in a plot allows you to make an estimate of the rest of the trees in the stand. For example, if you count 8 trees in a 10 x 10 metre plot, one hectare of woodland with the same average density would contain approximately 800 trees. Other inferences about the stand can be made from other information collected in the plot. If five of those trees were Sugar Maple, two were American Beech and one was a Hemlock, one hectare would contain approximately 63% maple (5/8), 25% beech (2/8), and 12% (1/8) Hemlock. Fixed area plots also let you estimate the number of taps/hectare (acre). This cannot be easily determined using a prism.

The Operating Plan

Your operating plan is a specific section of your management plan which details your short-term objectives. These objectives are in the form of a list of planned activities that you have determined are appropriate for your operation. Many of these activities are interconnected and should fall in a sequential order. Your operating plan should list them sequentially starting with the ones that need to be accomplished first. Take into consideration other factors which may influence your ability to complete a task – for example, do you need to develop a road to access the stand at the back of your property? Will your actions require you to modify your existing tubing system? If you are going to hire a logger, do you have one in mind and is he available? Have you tested the trees to determine which ones are sweeter?

*An **operating plan** is a document that lists what you plan to do over the next few years. Record your progress for each activity in the outcome column. Note that in this example only the first two implementation tasks of the first activity have been completed.*

Table 12: **5-Year Operating Plan Showing Planned Activities from 2005 to 2010**

Compartment	Year	Planned Activity	Implementation	Outcome
1	2006	• Thin to improve stocking	• Inventory Compartment 1 • Mark crop trees • Thin remaining trees to recommended levels	• Inventory completed in 2006 • Trees marked in fall 2006 • Marked trees will be cut over the next few years • Completed in_______
1	2007	• Install new tubing to access back of sugar bush	• Wait until compartment is thinned	
2	2006	• Improve drainage in low portion of compartment	• Hire backhoe • Avoid crop trees	
2	2009	• Harvest trees to improve growth of young maples	• Mark maple crop trees • Free crowns of crop trees by harvesting other species • Focus on removing cedar and Hemlock	

Thinning in the Sugar Bush

When done properly, thinning is an effective means of improving the overall health and productivity of your sugar bush. Removing the poorer-quality, slower-growing trees, frees up resources for those that remain. Stand growth can be dramatically improved by gradually removing unhealthy trees. It is even possible to turn an overcrowded, stagnant woodlot into one that is healthy, vigorous and productive through a series of planned harvests which encourage regeneration. Sugar bush thinning should be considered a very important and worthwhile aspect of sugar bush management.

It is however, critically important to follow good management practices when planning and thinning a sugar bush. Over-harvesting or employing poor harvest practices can damage a site so severely that it will take decades to recover. Harvesting should improve stand health not reduce it. Always follow the four cardinal rules when it comes to thinning and you and your sugar bush will benefit for years to come.

1. **Plan it well** – know what you are doing and understand why you are doing it. (See previous section on Management Planning)
2. **Mark your trees prior to harvest** – know which ones to leave and which ones to cut before you start your saw.
3. **Harvest properly** – the trees you are leaving are the future of the forest. Don’t damage them or the site they are growing on through poor harvest practices.
4. **Operate safely** – safety should always be a priority. Don’t jeopardize your future by cutting corners.

Harvesting should improve stand health not reduce it.

Some maple producers are reluctant to harvest tappable trees in their sugar bush because of concerns over a loss of overall productivity. While it is true that there may be a reduction in sap volume, careful planning and implementation will help minimize this. Keep in mind that good sugar bush management techniques promote the long-term sustainability of the sap harvest – over time it is possible to offset some tap losses through management. Consider the following points:

- Thinning your sugar bush will increase the growth of the remaining trees; this is especially true for smaller trees which will grow into tappable trees at an earlier age.
- Thinning operations can often be carried out over many years lessening any immediate tap loss.
- New areas of the sugar bush can sometimes be brought into production.
- Removal of the poorest trees with the smallest crowns or those with significant defects and die-back may not have much of an impact on overall sap production of the sugar bush; in many cases these trees would be poor sap producers in the first place.
- Harvested trees can be sold as fuel wood or timber – proceeds from wood sales can help offset tap loss. See Appendix C on page 125 for further information.

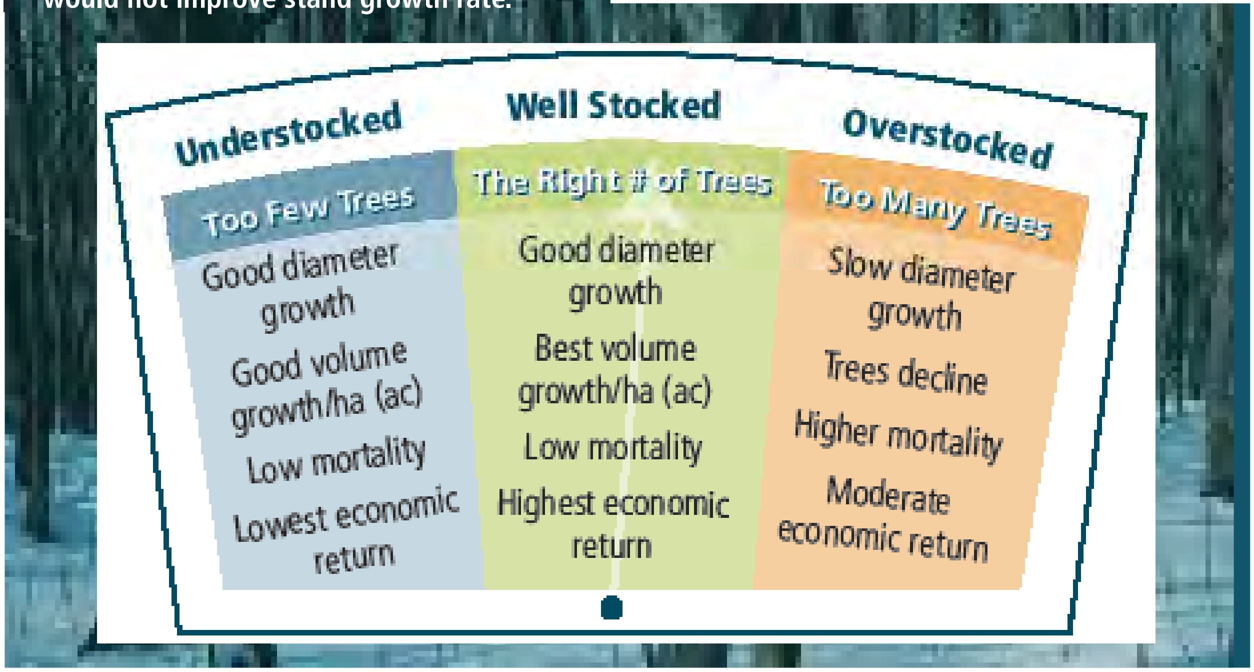
It is important to carefully consider all the implications of harvesting trees from your sugar bush before you begin. If you are in doubt, seek the advice of a knowledgeable forestry professional.

Implementing a Thinning Operation

Thinning activities require additional planning and preparation beyond what is involved in normal management planning. Similar to the management planning process, the activities associated with thinning your sugar bush can be thought of as a number of distinct steps. If you have identified thinning as a short-term objective in your Management Plan, it is first necessary to determine if it is warranted in the first place. If thinning is appropriate, the next step is to determine how much is recommended and what trees should be favoured for removal. Only after the planning is done can the stand be marked and finally harvested. These five steps are described in more detail in the following sections.

Figure 17: Where Does Your Sugar Bush Fit?

If your woodlot is overstocked, there are too many trees per hectare (acre). Thinning would be recommended to free up space and improve growth of the residual trees. If your woodlot is well stocked or understocked, there is adequate room for growth and thinning would not improve stand growth rate.



Step 1: Determining if Harvesting is Recommended

Harvesting is recommended under the following circumstances:

When your sugar bush is overstocked

Stocking is a forestry term used to describe whether you have too many or too few trees in your sugar bush for optimum growth. If there are too many, your sugar bush is said to be overstocked; if there are too few trees, it is understocked. If you have the right number of trees, it is said to be fully stocked.

Stocking is not the same as tree density which is a measure of the number of trees per unit area. For example, your sugar bush may have 150 trees/ha (60 trees/acre) but just knowing this number does not give you all the information necessary to make a decision whether there are too many or too few trees. In order to make this determination, you need to have some information about the diameter and other important characteristics of the trees. If those 150 trees per hectare (60 trees/acre) have an average diameter of 15 cm (6 in) there is much more room for them to grow than there would be if the average diameter was 55 cm (22 in). Stocking is discussed in further detail later in this chapter.

Thinning activities require additional planning and preparation beyond what is involved in normal management planning.

Why is Basal Area Important?

While it is true that most sugar bush operators have heard of the term Basal Area (BA), it is equally true that few of them have ever used BA to help them manage their woodland. BA is the sum of the cross-sectional areas of the trees in your woodlot and although it is a more difficult inventory statistic to measure, it provides an extremely useful tool for making management decisions. When expressed in terms of basal area per hectare (or acre), it becomes a measure of stocking which is independent of diameter – this means that you only need to know the BA of your stand in order to determine if it is overstocked, well stocked or understocked. BA is best collected with a prism but it can be calculated from fixed area plot data as well. Many forestry consultants prefer to use BA to determine relative stocking, and to help them mark the forest prior to harvesting. Basal area is not used to determine the stocking of seedling or sapling sized trees – in stands where you need to determine if thinning smaller trees is warranted, the number of trees per hectare (per acre) (density) will suffice.

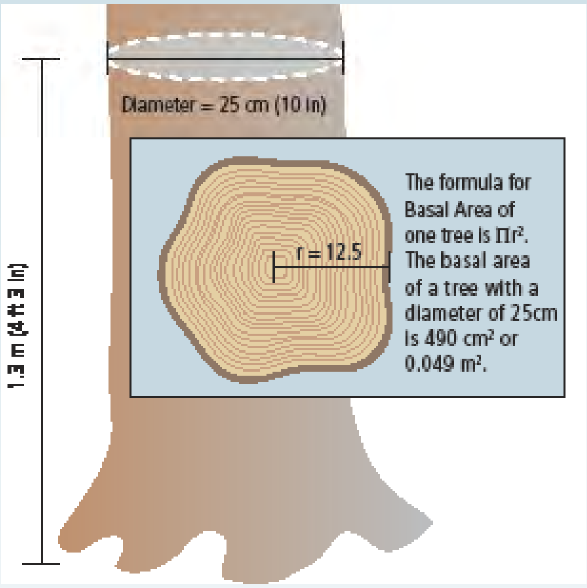


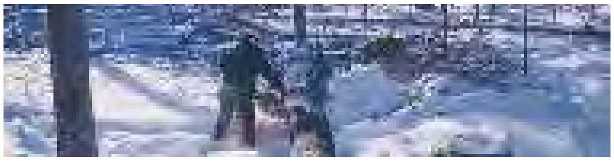
Figure 18: **Basal Area**

For additional information on Basal Area and its implications on sugar bush management *see Appendix D, p 127.*

When you want to promote maple regeneration

It is recommended that a sugar bush contain at least 5000 seedlings/ha (2000 per acre) in order to ensure that maple continues to dominate in the stand. 5000 seedlings/ha is the same as one seedling for every $2m^2$. If the number of seedlings is significantly less than this, thinning to promote maple regeneration may be warranted. To accomplish this you should:

- Remove individual trees to allow more light to reach the forest floor.
- Remove non-maple species which may produce seedlings that compete for space with maple regeneration; this is especially true for faster growing shade intolerant species like birch and aspen.
- Minimize soil exposure; avoiding site disturbance and maintaining a thick litter layer on the forest floor promotes maple regeneration. Exposed mineral soil promotes the germination of other species.
- Harvest in the winter to minimize site damage, to limit the spread of intolerant species and to protect existing desired species.



In most cases you will be able to promote sufficient regeneration through normal sugarbush thinning practices such as crop tree release.

When your sugar bush has suffered storm damage

If your woodlot has been impacted by severe weather it may warrant a salvage cut to:

- Access commercial timber that will be lost to decay
- Release smaller, undamaged trees which survived the storm
- Remove undesirable species which may seed into damaged areas

It is recommended that a sugar bush contain at least 5000 seedlings/ha (2000 per acre) in order to ensure that maple continues to dominate in the stand.

Step 2: Determining How Much To Harvest

If the analysis of your inventory data tells you that your sugar bush is overstocked and that thinning is recommended, the next step is to determine how much needs to be thinned. You want to bring your sugar bush closer in line to what is recommended by cutting out some of the trees and changing its stocking value from overstocked to adequately stocked.

The recommended number of trees to harvest is a function of:

1. What you have now (as determined by your inventory)
2. Your sugar bush operational needs
3. The determined stocking level for your particular woodlot.

The number of trees to harvest is usually expressed in terms of a reduction in stocking levels for the woodlot – for example, you may need to reduce the basal area by a certain percentage in order to bring your sugar bush closer in line with what is recommended. For additional information on Basal Area and its use in sugar bush management see Appendix D, page 126.

In some cases, especially for even-aged stands, this number may be expressed in terms of number of trees. You may need to harvest a certain number of trees of specific sizes per hectare; for example, it may be recommended that 4 trees in the 25 to 37 cm (10–15 in) size class be removed per hectare. In a 10 ha (25 acre) sugar bush that would mean harvesting approximately 40 trees within this particular size range.

The number of trees to harvest or leave is a management recommendation and it is important that you are comfortable with it. You may decide to follow the recommendation or you may not – it is your decision. You may also decide to harvest them all at once, or you may want to harvest them over a number of years.

In many cases the proceeds from the sales of harvested sawlogs, veneer and fuelwood will help offset the loss of syrup production caused by a reduction in the number of taps. For more information on how a harvest can offset production loss see Appendix C, page 125.

Step 3: Developing a Prescription for the Sugar Bush

Once you have developed management recommendations for the stand, it is important to develop a list of instructions on how to apply them in your sugar bush. These instructions are called a management prescription for the stand in question. They provide rules and guidance on:

- Which trees to harvest (harvest trees)
- Which trees to leave (crop trees)
- How the trees will be marked (Step 4)
- When the work is to be completed

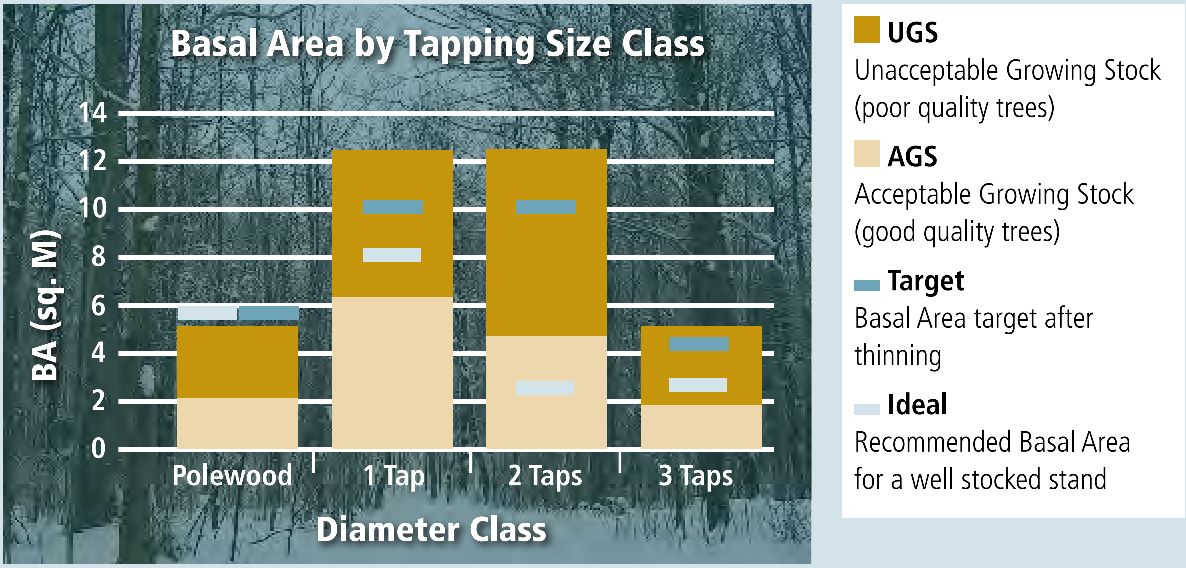
A management prescription is a list of instructions which helps you or a tree marker identify trees in the field. The following example shows a prescription developed from an inventory of a sugar bush in central Ontario.

Stand Prescription:

An Example

Short-term Objective: *thin 3 ha (7 acre) compartment to improve health and productivity of stand.*

Figure 19: **Inventory Summary**



Prescription:

Thin approximately 20% of the Basal Area in the compartment

- Do not mark any trees within 10 m (33 ft) of western property boundary – keep intact as wind buffer to reduce chances of blow-down.
- Identify all good quality polewood maple stems – mark them as crop trees with blue paint.
- Favour the retention of all polewood trees unless obviously declining.
    - Declining trees (UGS) will be in poor health or form and unlikely to survive or grow into a productive crop tree.
- Mark for removal with yellow paint 1 out of 5 maples in the 1-tap and 2-tap size class (>37 cm); focus on the poorest quality.
- Keep all healthy (AGS) single tap and 2-tap maples.
- Mark for removal 50% (1 out of 2) beech which are greater than 25 cm (10 in).
    - Choose poorest quality beech .
- Leave representative non-maple species for biodiversity.

Marking the stump allows you to check that the right trees were removed during harvesting operations.

STEP 4: Tree Marking – Preparing your woodlot for harvest

The next step is to apply the prescription to the sugar bush by identifying and marking individual trees according to the prescription.

Trees may be marked with coloured, non-oil based tree paint. For trees that will be harvested, a stripe of paint is applied to the main trunk at about eye level and a dot of paint is applied to the base of the tree below the stump cut line. Marking the stump allows you to check that the right trees were removed during harvesting operations. All trees should be marked on the same side so that the markings can be seen from one direction but many professional tree markers prefer to identify the tree on two or more sides for better visibility throughout the sugar bush.

Marking the trees prior to harvest clearly identifies which ones to cut and which ones to leave. Although you may use a common marking scheme, you may prefer to use one of your own design to mark crop trees as well as those which will be harvested.

It is important to follow a common colour coding system throughout the sugar bush to avoid confusion, particularly if other people will be involved in tree removal. Choose a marking scheme that is right for your operation and area. The following outlines one possible colour convention for tree marking in a sugar bush.

- **Boundaries** – Red paint is used to mark boundaries of the woodland. Be sure that the neighbours agree with the boundary lines.
- **Harvest Trees** – Yellow or orange paint is used to mark trees for removal. If a second party is removing the trees, a mark should be made below the stump level as well as one at breast height. This provides a means of verifying that only the marked trees are being removed.
- **Crop Trees** – Vigorous young trees that have been selected as possible future crop trees should be marked with blue paint.
- **Tappable Trees** – Crop trees that are large enough to tap can be painted with white paint at breast height, one dot per tap.

It is important to note that not every tree in your sugar bush needs to be marked as either a crop tree or a harvest tree. In fact, many trees are not marked at all. Unmarked trees help maintain adequate stocking levels in the sugar bush and may, or may not, be identified and removed during subsequent thinnings. Because there are usually many more potential harvest trees than crop trees you will need to be mindful that you do not mark too many.

Step 5: Harvesting Operations

The prime objective of a commercial maple operation is to maximize the production and sweetness of maple sap from the sugar bush in a sustainable manner. This will involve the removal of timber from the sugar bush during thinnings. These trees may be used by the producer for fuelwood or milled up into lumber for use around the sugar camp. Harvested logs may also be sold as veneer logs, sawlogs, fuelwood, or pulpwood to supplement income from the sugar bush. Take time to research markets so that maximum profit can be realized for the timber harvested; wood prices can vary from year to year.

Tapping creates internal stain patterns which will degrade the quality of the tree. Generally however, only the first 2–3 m (6 to 9 ft) is affected and the tree will usually yield one or two sawlogs. Maple butt logs (first log above the stump) with old tapping scars are sometimes milled and sold as specialty lumber. If you plan to do this beware of old metal spouts that may be buried in the wood.

A producer may harvest his own timber or tender the job out to a logger. If you opt to bring in a logger to do the work, the following is recommended:

1. **Tender the harvesting operation** to at least **three** reputable operators to help ensure a fair price and adherence to proper forestry practices.
2. **Check references** to ensure that the logger is reputable and performs high quality work.
3. **Do not let the logger mark the trees** – do it yourself or have a certified tree marker with experience in sugar bushes do it for you.
4. **Sign a contract** with the logger clearly laying out the responsibly of each party and the expected date of completion – the contract is there to fall back on if something goes wrong, so ensure that your rights as a landowner are protected. Sample contracts are available through the Ontario Woodlot Association.
5. **Monitor the logging activity daily** – your presence, or that of a forestry professional, on the job site will go a long way to ensuring the job is done well.

Maple Sawlog and Pulpwood Prices Over the Years

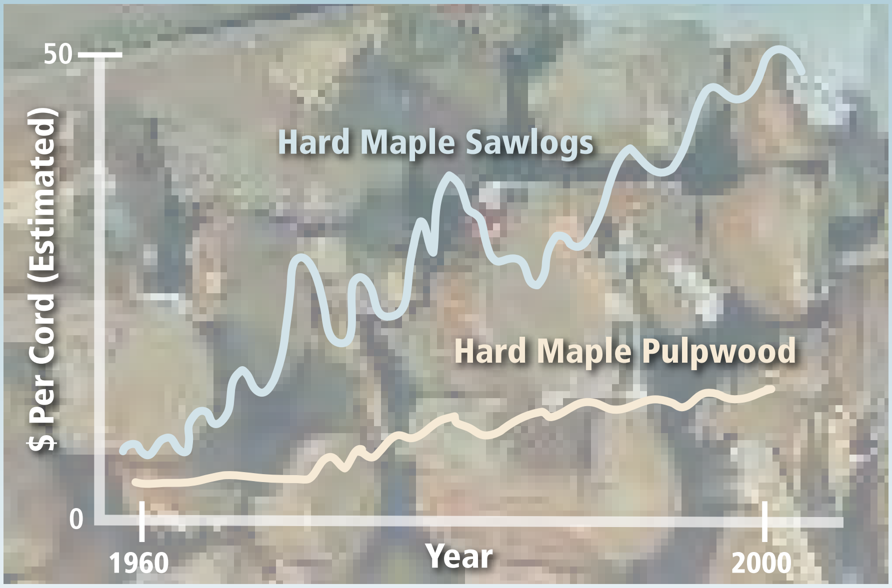


Figure 20: **A Comparison of Prices for Maple Sawlogs and Pulpwood (1960 – 2000)**

Although the average price for maple sawlogs has increased steadily over the past few years, there can still be considerable variation in the potential value of the timber. Prices paid for timber are affected by:

- Regional value of timber
- Local economic conditions – nearness to processing facility
- Species marked for harvest
- Diameters of the cut trees
- Log quality or grade
- Annual or periodic fluctuations in supply and demand
- Logger hired to harvest the trees – some loggers will pay more than others
- Accessibility of the woodlot

Logging practices must minimize damage to remaining trees and the site. They should be conducted effectively and safely.

Improvement cuts may be conducted every 10 to 15 years in a given stand, depending on sap productivity and tree health and growth. This time interval also corresponds with the typical lifetime of a tubing installation. Because of this, it is beneficial to coordinate thinning with tubing replacement for ease of harvesting operations. Changing the sap collection system periodically will also allow the producer to take advantage of the latest innovations in the industry for efficient sap collection.

Some producers however, opt to stage their improvement cuts over a period of years, harvesting fewer trees at any one time. Changes to the structure of the sugar bush are brought on gradually and at a pace that allows the producer to monitor the impacts of harvesting. A producer who chooses to manage his sugar bush in this manner, will need to work around existing tubing infrastructure modifying it as necessary to compensate for harvested trees. Some modern tubing systems are designed to facilitate harvest and thinning operations.

References like this one available through the Ontario Woodlot Association are excellent sources of help and additional information.

Careful planning of skid trails can help minimize unnecessary damage to residual trees.

Logging practices must minimize damage to remaining trees and the site. They should be conducted effectively and safely. Some points to consider when preparing to harvest in a sugar bush are as follows:

- **Follow the Sugar Bush Management Plan** – Objectives and timing of harvest should be organized in the management plan.
- **Timing** – Thinning when the trees are younger greatly increases the growth and desirable characteristics of crop trees. Once a tree matures, it does not respond as well to release. The depth of the crown is already established in mature trees. Releasing them from competition may allow the remaining trees to develop broader but not deeper crowns.
- **Time of Year** – September to late winter is generally the best time for harvesting. Avoid harvesting any time the soils are wet to avoid soil compaction. It is best not to harvest during the active growing season (May until July) because the trees are more easily damaged. Harvesting should also be postponed following any heavy insect defoliation to allow the trees to recover.
- **Degree of Canopy Opening** – Releasing the crowns of selected crop trees is important but it is very important to not harvest too many trees at any one time. Opening the canopy up too much may allow too much

light to reach the forest floor, resulting in a number of potential problems including: the promotion of epicormic branching and sun scald; increased windthrow; increased levels of soil drying; increased incidence of Sugar Maple Borer; and, the germination of undesirable species. Achieving the optimal stocking levels for your sugar bush may involve several thinnings carried out over a number of years.

- **Minimize Damage to Remaining Trees** – Carefully plan the felling and skidding of each tree to minimize damage to remaining trees. Damage creates an entry point for infection by disease organisms. Trees should be felled away from skidding trails for ease of skidding. Use a winch and cables to keep skidder / tractor traffic through the bush to a minimum. Leave marked bumper trees along skidding trails where possible to prevent rubbing damage to crop trees. Hire a reputable logger to do the thinning, if you will not be doing the work yourself.
- **Minimize Damage to the Forest Floor** – Machinery and horses should be kept on existing roads as much as possible. Do not use heavy machinery in the sugar bush when the ground is soft. Logging should be conducted when the soil is dry or in the winter when the ground is frozen. Working when the ground is soft can result in severe compaction or rutting of the soil and damage to tree roots.
- **Response of older trees** – Older, mature trees do not respond to thinning with an increased growth rate as do younger, more vigorous trees. Any thinning, other than that which is light, may actually initiate decline within a stand of overmature or severely stressed trees.
- **Safety** – Ensure a safe working environment while harvesting in the sugar bush. Use appropriate safety gear and precautions.

Harvest with care and safety in mind. No amount of money or savings is worth the cost of a serious injury. Take a chain saw safety course and do not exceed your capability. Many people get hurt working in the bush; you should use the buddy system and have quick access to a phone or walky-talky in case of emergency.

Harvesting Techniques for Different Types of Sugar Bushes

The five steps for implementing a harvest operation can be applied to every sugar bush in Ontario. However, the harvest recommendations which are determined in Steps 2 and 3, vary depending on the individual characteristics of the sugar bush being managed. Your sugar bush has a number of qualities which are used to determine:

- How many trees to harvest
- What species should be harvested
- What size of trees need to be harvested

The unique nature of each sugar bush means that a common set of management guidelines such as thinning recommendations can not be developed. As a result, the harvest recommendations for a stand of young maples will be different from that of a mature sugar bush, as will the thinning recommendations for your sugar bush compared to your neighbours. In addition, the harvest recommendations for specific compartments within your sugar bush may also vary depending on the site characteristics and stand structure.

The unique nature of each sugar bush means that a common set of management guidelines such as thinning recommendations can not be developed.

Older, mature trees do not respond to thinning with an increased growth rate as do younger, more vigorous trees.

If your inventory shows that the diameter distribution in your sugar bush resembles that of the graph below, your sugar bush is uneven-aged.

How old is that tree anyway?

Determining the age of individual trees within your sugar bush can be done by counting the growth rings – one ring equals one year. If you cut down a tree, determine its age and calculate its average growth rate by counting the number of rings per centimetre (inch). Note the variation in ring sizes over the years, which is caused by changing growing conditions and environmental factors.

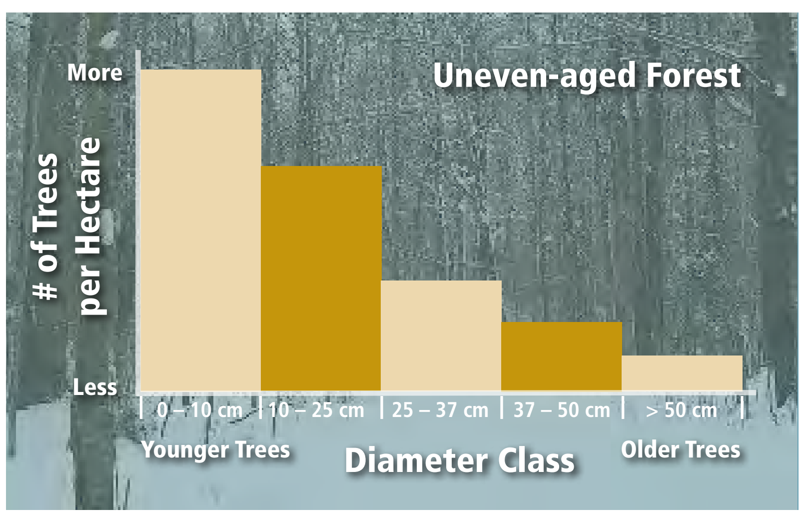
Even though we talk about stand age and how it influences management, it is often not practical to figure out what the actual age of a stand is, especially in a hardwood stand where there can be considerable variation in ages even among trees of the same size. For this reason, it is better to use tree diameter as a general indication of age – in most cases, young trees tend to be smaller in diameter than older trees. If most of your trees have diameters which are around the same size, your woodlot is probably even-aged. If your trees are highly variable in diameter with a distribution similar to the graph in Figure 21, your woodlot is probably uneven-aged.

There are some potential draw backs to using diameter as a general indication of age, especially in stands with a large number of suppressed trees. A tree that has been suppressed for many years may be the same age as larger trees which were not suppressed. Generally, however, these trees do not show signs of vigorous growth and can be easily identified in the sugar bush.

Management Techniques for Uneven-aged Sugar Bushes

If your inventory shows that the diameter distribution in your sugar bush resembles that of the graph below, your sugar bush is uneven-aged. Stands that are uneven-aged have a distribution of age classes from young regeneration right up to large mature trees. You will note in the following diagram that the number of young and old trees in the graph is not evenly distributed. This represents the ideal situation where there are many more younger trees than there are larger ones and there are trees of every diameter present in the sugar bush.

Figure 21: **Ideal Distribution af Ages and Diameters in an Uneven-aged Forest**



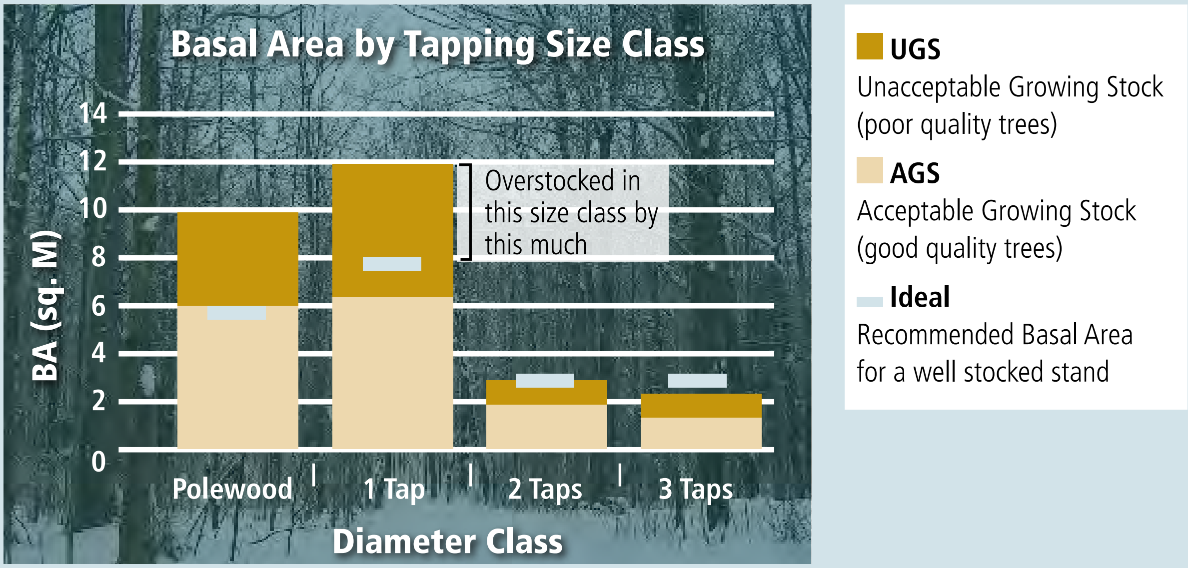
As illustrated in Figure 21, there are many small, and relatively few large trees in the uneven-aged sugar bush. This occurs because an area of land can only support so much biomass. Sugar Maple is a prolific seed producer but of the millions of seeds that can fall in a sugar bush during a good seed year, only a few thousand will find a suitable site for germination and grow into a healthy seedling. In turn, these seedlings must constantly compete for resources throughout their life. If a particular seedling is able to access enough light, water and nutrients, and if it is lucky enough not to be severely impacted by other factors like insects, disease, very dry weather and animals, it may survive until it occupies a dominant position in the crown as a mature tree. Consequently, it takes the germination of many seeds to ensure that one tree will grow to maturity.

In all probability your sugar bush will plot differently than the ideal distribution of diameters for the uneven-aged stand represented by Figure 21. Management guidelines for uneven-aged sugar bushes recommend the removal of poorer-quality trees in overstocked size classes in order to adjust the total number of trees per hectare (acre) and bring the sugar bush closer to the ideal. This concept is demonstrated in Figure 22, below.

In this chart, Basal Area is used as the determinant for stocking. The BA is known for each size class and can then be compared to the ideal (recommended) BA value. The number of trees in each size class can also be used in a similar way as a means of determining stocking. Table 13, page 56 can be used to compare your uneven-aged sugar bush to the ideal uneven-aged sugar bush. It

Figure 22: Inventory Data Showing Overstocked Condition in Some DBH Classes

Managing the uneven-aged forest means removing trees in diameter classes which have more than the recommended number of stems. In the example illustrated by the graph below, there are two diameter classes (Polewood, 1 Tap) which have more trees than the ideal; most of the trees harvested in this woodlot would come from these classes. Trees in understocked (3 Taps) or ideally stocked (2 Taps) classes would not be cut unless absolutely necessary. Note how the graph also displays the proportion of good (AGS) and poor (UGS) trees. UGS trees are selected first when marking trees to harvest, depending on species; e.g., a UGS Sugar Maple with potential to tap for 10–15 years should be retained over a UGS Ash.



Management guidelines for uneven-aged sugar bushes recommend the removal of poorer-quality trees in overstocked size classes in order to adjust the total number of trees per hectare (acre) and bring the sugar bush closer to the ideal.

Table 13: Recommended Number of Crop Trees in a Well-stocked Uneven-aged Sugar Bush

Diameter Class	Recommended Crop Trees per Ha	Average Taps per Diameter Class
Sapling 2.5–10 cm (1–4 in)	60 to120	—
Polewood 10–24 cm (4–10 in)	40 to 90	—
1 Tap-tree 25–37cm (10–15 in)	25 to 35	25 to 35
2 Tap-tree 37–50 cm (15–20 in)	18 to 25	36 to 50
3 Tap-tree >50 cm (>20 in)	10 to 20	30 to 60
Total	**153 to 290**	**91 to 145**

Table developed by Mark Richardson, adapted from the *Ontario Tree Marking Guide*, OMNR. 2004. Version 1.1. OMNR, Queen's Printer for Ontario. Toronto. 252p.

Healthy, vigorous maple AGS crop tree.

UGS Maple with severe crown damage

provides a guide for determining if you are over or under-stocked in the various diameter classes. You will notice that there is a significant range in the number of crop trees recommended for each diameter class. These numbers reflect different growing conditions in Ontario. In some parts of the Province for instance, site and growing season limitations make it more difficult to grow larger maples. In these areas, 10 crop trees per hectare (4 per acre) with a diameter greater than 50 cm (20 in) is a more realistic target than 20 crop trees per hectare (8 per acre).

The numbers in Table 13, represent management targets for uneven-aged sugar bushes. For example, you should strive to have somewhere between 60 and 120 sapling-sized crop trees, along with 40 to 90 polewood-sized crop trees and so on down the list. Your inventory will tell you what you have in each of the five diameter classes; if you have more than what is recommended for a particular diameter class, it is probably overstocked.

Basal area offers the best method of determining if your uneven-aged sugar bush is overstocked and should be thinned. It also provides a quick means of determining how much needs to be thinned at any one time. If your sugar bush has a basal area of 24 m^2/ha (105 sq.ft/ac) or greater it is most likely overstocked and some thinning would be warranted. For example, if a sugar bush has a BA of 28.5 m^2/ha (124 sq.ft/ac), it is overstocked and lowering the BA by 4.5 m^2/ha (20 sq.ft/ac) (16%) would not be unreasonable. Appendix D provides additional information on the use of basal area.

Management Techniques for Even-Aged Sugar Bushes

In even-aged sugar bushes management options are relatively straightforward and dependent on how young (small) or old (large) the trees are. If you look at your inventory data and determine that the distribution of diameters looks something like the graph in Figure 23, your woodlot is even aged. This does not mean that you do not have trees which are younger and/or older. It means that the majority of trees in even-aged forests are close in age and, correspondingly, in diameter.

Even-aged sugar bush management uses average diameter and tree density as the key determinants of stocking. If you know your average diameter and the number of trees per hectare (acre) you can easily determine if your stand is overstocked.

Table 14 shows a stocking table for even-aged stands. If for example your sugar bush had an average diameter of 31 cm (12 in), Table 14 tells us that there should be somewhere between 150 and 210 trees/ha (60–85/ac) for it to be well stocked. Please note that this number would include all the trees in the sugar bush and not just those selected as crop

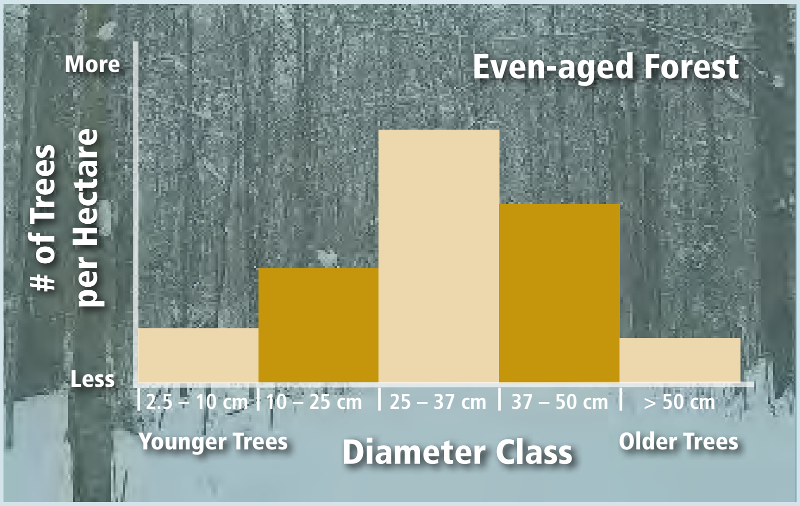


Figure 23: **Graph Showing Tree Distribution in an Even-aged Forest**

When plotted on a graph, an even-aged forest will have a diameter distribution similar in shape to the one displayed in Figure 23. Although there are always smaller and larger trees, the majority of them will be grouped around one diameter class (range). In this case, it is in the 25 to 37 cm class.

Table 14: **Recommended Number of Crop Trees for Well-stocked, Even-aged Sugar Bushes**

Average Stand Diameter	Taps Per Tree	Recommended Number of Trees		Maximum Potential Number of Taps	
		per Ha	per Acre	per Ha	per Acre
less than 10 cm					
(less than 4 in)	0	more than 680	more than 275	0	0
10 – 25 cm (4 – 10″)	0	210 – 680	85 – 275	0	0
25 – 37 cm (10 – 15″)	1	150 – 210	60 – 85	150 – 210	60 – 85
37 – 50 cm (15 – 20″)	2	100 – 150	40 – 60	200 – 300	80 – 120
> 50 cm (> 20″)	3	67 – 100	27 – 40	200 – 300	80 – 120

Table adapted from Coons, C.F. 1992, Koelling, Melvin R. and Randall B. Heiligmann. 1996 and, Morrow, R.E. 1976 trees. It is possible to narrow the recommended number of trees down by looking at where your average diameter is within the diameter class 25–37 cm (10–15 in). If the average diameter is 31 cm (12 in), which is in the middle of the range, this stand should have roughly 180 trees per hectare (halfway between 150 and 210). If you have fewer than 180 trees/ha (73 trees/ac), your sugar bush is understocked and thinning would not be recommended. If there are more than 180 trees/ha (73 trees/ac), thinning is recommended because your sugar bush is overstocked.

There is always some variability in a sugar bush and even-aged stands are no exception. There may be a range of diameters, ages and tree locations that make it more difficult to apply Table 14 in the field. Your even-aged sugar bush may have pockets of smaller trees and areas where larger trees seem to be clumped together. Keep in mind that the numbers of stems per hectare (acre) are based on theoretical conditions where all the trees are the same size and spaced at equal distance from each other. Inventory information from your sugar bush can be compared to this table as a means of determining how well stocked it is, but you will still need to interpret the number recommended based on your particular circumstances.

Keep the following points in mind as you work through the development of a management prescription:

1. Check to see that there is adequate maple regeneration; if there isn't, you may have to change your harvest plans to promote the growth of maple seedlings.
2. At the very maximum, reduce the stocking by no more than 33% (1/3) at any one time; it may be more appropriate to keep your harvest level at 20% or less.
3. Stocking should still be interpreted using basal area per hectare. If the initial stocking is higher than 24 m^2/ha (105 sq.ft/ac), thinning is recommended. If it is below this value then caution is warranted.
4. It is better to carry out the harvest through a number of small cuts spaced out every 10 to 15 years rather than one large one; some producers like to thin their sugar bushes just before they install new tubing systems.
5. Do not remove more than what is recommended; try to keep your stand at the well stocked level rather than the understocked.

In summary, the following general management steps can be applied to any even-aged sugar bush.

1. Determine the average diameter and density of trees.
2. Look up the average diameter on the stocking table.
3. Interpret these results based on conditions in your sugar bush.
4. Make recommendations for thinning.

Selecting Trees in Your Sugar Bush

Now that you know the general age structure of your sugar bush, and you have determined that thinning is warranted, it is time to apply the prescription to the woodlot. Tree marking involves selecting individual trees within the woodlot. Some of the trees selected will not be harvested; these are your crop trees. Some of the trees selected will be harvested; these are your removal trees. Some of the trees will not be selected as either crop trees or harvest trees; these will be left for future management activities. This section details information on marking individual trees within your sugar bush – the recommendations within it are dependent on the age and diameter distribution.

Crop Tree Selection – Identifying What to Leave

Sugar bush management differs from timber management in a number of distinct ways. Perhaps one of the most significant is the need to identify crop trees before other trees are marked for removal. A crop tree is a tree you plan to leave in the sugar bush, that will not be harvested for a specific reason. In most cases, a crop tree is a tree you plan to tap for sap production but it may also be one left for sugar bush protection, for diversity or for future timber value.

Look for the following characteristics when selecting crop trees for syrup production:

- Select the healthiest maples, free from signs of disease, insects, defects, damage or stress.
- Select trees with good form (shape) that have well defined leaders.
- Select the tallest, single stem maples, with the widest, deepest crowns.
- Depending on the site, preference should be given to Sugar and Black Maple over Red and Silver Maple.
- Preference should be given to trees that originated from seed over ones that developed from stump sprouts.
- Use sap sweetness as a factor when choosing between trees with similar physical characteristics (see page 124, Appendix B).
- Select trees according to the developed prescription. Your prescription will recommend trees of different sizes as those to favour for retention – for example: “retain between 60 and 85 AGS maples per hectare in the 25 to 37 cm diameter class”.

Can a species other than maple be selected as a crop tree?

The answer to this question is yes – although most of your crop trees are going to be sap producers it may not be inappropriate to select a species other than maple if:

- There isn’t a maple tree of the same size and quality near it in the canopy
- It is necessary to keep it in order to maintain the recommended stand structure (number of trees of different diameters)
- It may provide additional income in future harvests as a sawlog or veneer log
- It acts as a buffer, protecting other areas of the sugar bush
- It provides species diversity (see page 25)

Background image: Basswood tree

Harvest Tree Selection – Identifying What to Cut

Generally, the poorer quality trees (UGS) are marked for removal in the sugar bush but occasionally, a high quality tree may need to be selected if it interferes with nearby crop trees. Consider the following characteristics when selecting removal trees:

- Trees with stem injuries and deformities that exhibit signs of disease or decay (refer to the Forest Pest Management section of this manual for information regarding major forest disease and insect pests)
- Trees with very small crowns
- Trees with forked main stems
- Trees with poor crown position
- Trees with coarse branches within the tapping zone
- Trees with lower sap sweetness. (see page 123, Appendix B)
- Over-mature maple trees – remove these trees while they are still valuable as marketable timber or fuelwood
- Any trees that are a danger to the safety of people in the sugar bush
- Undesirable species especially Balsam Fir, aspen and birch (refer to the Biodiversity section in this manual)
- Other shade-tolerant species, like American Beech, when they make up a significant portion of the species composition. American Beech is an aggressive competitor with Sugar Maple, particularly on drier sites. The leaves of American Beech trees are slow to decompose and when abundant can inhibit the establishment of Sugar Maple regeneration. American Beech should be kept at less than 20% of stand composition.
- Nut trees may be removed to discourage large populations of squirrels.
- Select trees according to the prescription – favour trees of different sizes for removal.

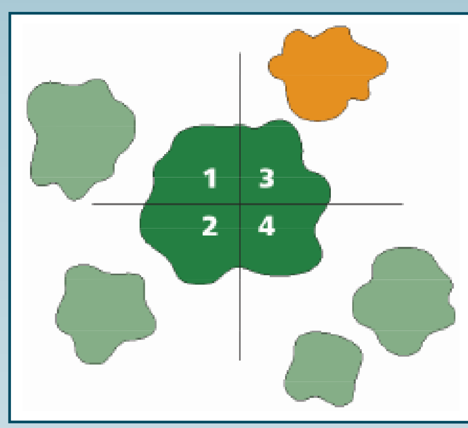
Releasing Crop Trees

When a crop tree has been identified and marked, it is necessary to give it the space it needs to grow. This is done by harvesting some of the trees around it. These trees are first marked as harvest trees and then removed, thereby freeing up resources for the remaining crop tree. This practice is known as '*Crop Tree Release*' and it represents the best way of improving the overall health and productivity of your sugar bush. Crop tree release applies equally to both even- and uneven-aged sugar bushes. The main difference is that there may be an overstory of trees larger than the crop trees in an uneven-aged stand. These larger trees often provide some protection from heat and other weather extremes.

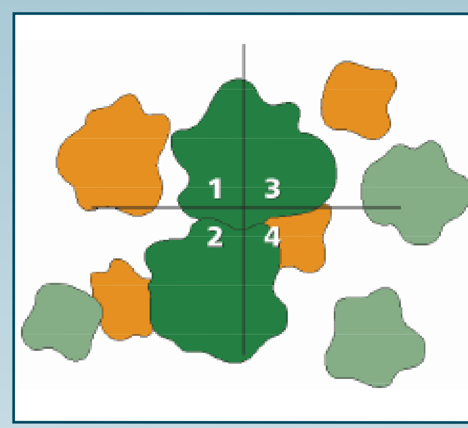
When marking your sugar bush, you have a rough idea of the number and sizes of trees that need to be harvested as well as protected – this was determined through the development of the prescription. Following the prescription should help you avoid problems caused by over harvesting, which will lower the stocking to an unacceptable level. It is important to keep in mind that simply identifying crop trees and harvesting all the trees around them may not achieve your management objectives. You need to ensure that the trees marked are acceptable according to the prescription.

Figure 24a: By dividing the crown of a crop tree up into 4 quadrants it is easy to see that this crop tree is free-to-grow on 3 sides – sides 1,2 and 4.

Figure 24b: If two crop trees are close together they can be treated as one single stem by removing competing trees around them.

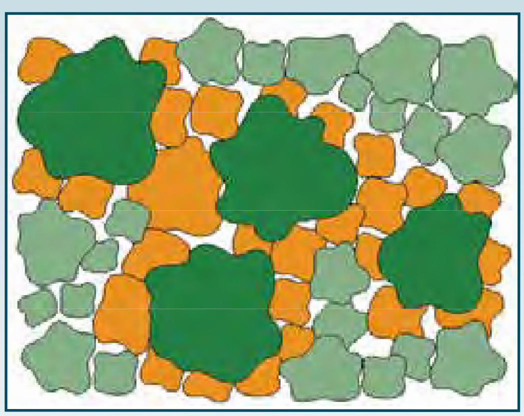


a

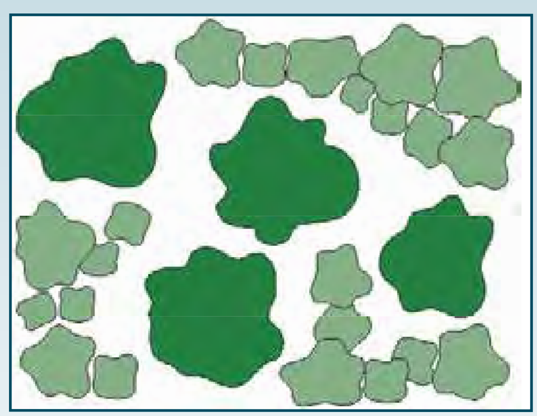


b

Figures 24c, d: Your sugar bush may look something like this before (c), then after (d) the crop trees have been released. In this example, the basal area was reduced to an appropriate level, which left numerous clumps of unharvested non-crop trees.



c: Before release



d: After release

Crop trees | Non-crop trees | Trees marked for removal

Adapted from *Crop Tree Managemment in Eastern Hardwoods.* Perkey, Wilkins and Smith. USDA Forest Service.

It is important to provide enough room for the crop tree to grow but not so much room that it is subject to adverse health impacts, such as sunscald damage. Also, remember that very wide spacing may result in an influx of unwanted trees and shrubs, particularly in the absence of a protective overstory of larger trees. To this end, a general tree spacing guideline has been developed which lists how far away neighbouring trees should be from selected crop trees. This information is provided in Tables 15a (Metric) and 15b (Imperial).

For example, if you had a crop tree which was 25 cm (10 in) in diameter; it should be approximately 7 m (23 ft) away from another 25 cm (10 in) tree. It should be about 6.4 m away from a 15 cm (6 in) tree. If a 15 cm (6 in) tree was 5 m away from the 25 cm (10 in) crop tree it could be selected as a removal tree because it is too close to the crop tree for optimal growth.

It is important to provide enough room for the crop tree to grow, ... remember that very wide spacing may result in an influx of unwanted trees and shrubs, particularly in the absence of a protective overstory of larger trees.

Table 15a: **Recommended Spacing in Metres Between Adjacent Trees**

Diameter (cm)	10	15	20	25	30	35	40	45
10	4.7	5.1	5.5	5.8	6.7	6.8	7.2	7.7
15	5.1	5.5	6.0	6.2	7.0	7.1	7.5	8.0
20	5.8	6.1	6.4	6.6	7.3	7.5	7.8	8.2
25	6.1	6.4	6.7	7.0	7.6	7.9	8.2	8.6
30	6.2	6.7	7.0	7.3	7.9	8.2	8.6	9.0
35	6.6	7.0	7.3	7.6	8.2	8.5	8.9	9.3
40	7.2	7.6	7.9	8.2	8.5	8.8	9.4	9.7
45	7.5	7.9	8.2	8.5	8.8	9.2	9.7	10.0

Table 15b: **Recommended Spacing in Feet Between Adjacent Trees**

Diameter (inches)	4	6	8	10	12	14	16	18
4	15	17	18	19	22	22.3	24	25
6	17	18	20	20.3	23	23.3	25	26
8	19	20	21	22	24	25	25.5	27
10	20	21	22	23	25	26	27	28
12	20.3	22	23	24	26	27	28	30
14	23	24	25	26	27	28	29	30.5
16	23.6	24	25	26	27	29	31	32
18	25	26	27	28	29	30	32	33

Please note that these numbers should be used as a general guideline when determining which trees to remove around a selected crop tree. They must be interpreted based on your sugar bush and its current level of stocking, its diameter distribution and its overall health.

Crop Tree Release in Even-aged Stands

Stands with an average diameter below 10 cm (4 in):

These sapling sized trees should be thinned by removing competing crowns around the best stems – provide approximately 1 to 2 metres (3–7 ft) of space around the outside of the crown. Extra care should be taken not to damage the stems of the selected future crop trees during the thinning operation. You can expect that the stand will need another thinning in approximately 5 to 10 years.

This method of thinning regeneration also works for managing young trees growing in openings of established sugar bushes. Although regeneration is often present in sugar bushes with a closed canopy, it does not grow vigorously until an opening is created, allowing sunlight to reach the forest floor. The removal of one or more mature trees allows more light to reach the existing seedlings giving them a competitive head start over other species which might have to seed into the opening. After a few years, the trees will have grown considerably and thinning may be necessary.

Stands with an average diameter between 10 and 25 cm (4–10 in)

Often referred to as a polewood stand, you can expect to have 210 or more crop trees per hectare (85 trees/acre). If your inventory has shown that you have an overstocked polewood stand with few or no tappable trees, it will most certainly benefit from thinning. Maple stands in the polewood 10 to 25 cm (4–10 in) size class have been shown to grow dramatically after they are thinned provided the residual trees haven't been suppressed for an extended period. Releasing crop trees in these types of stands is a simple matter of identifying the best trees (according to the selection criteria listed previously) and removing the trees around them which have interfering crowns.

Although regeneration is often present in sugar bushes with a closed canopy, it does not grow vigorously until an opening is created allowing sunlight to reach the forest floor.

Top View Showing Regeneration in a Canopy Opening

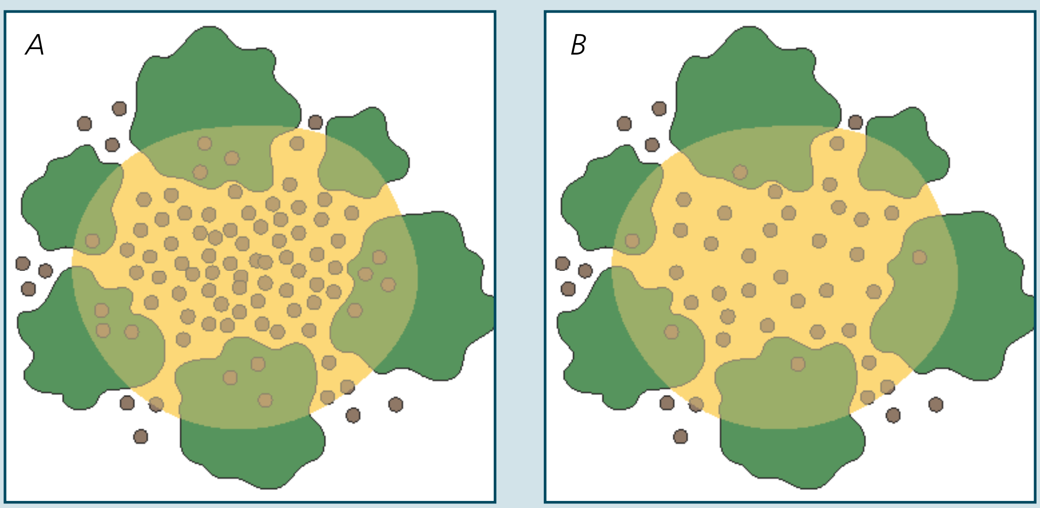


Figure 25a: Shows regeneration within an opening in the canopy before thinning.

Figure 25b: Shows the same regeneration after thinning. Saplings have been thinned to approximately 2 m (6.5 ft). The base of the trees that surround the opening defines the perimeter of the area to be thinned.

Stands with an average diameter of 25 to 37 cm (10–15 in) 1 tap:

These stands still respond well to thinning but may not respond as well as younger stands especially if the stand has not been previously thinned. If this is the case, reduce the recommended thinning levels and consider thinning more frequently. Monitor the impacts of thinning. If your stand has been thinned previously, thin to the recommended levels. In either case, selecting the best crop trees is critical – try to find between 150 and 210 per hectare (60–85 per acre). This represents one crop tree every 6 to 8.5 metres (20–28 ft).

Stands with an average diameter of greater than 37 cm (15 in) 2 taps and up:

In overstocked mature stands it is unlikely that thinning will result in a dramatic increase in growth. In these sugar bushes, the trees will respond but this may not mean an increase in overall sugar bush productivity. Thin conservatively in these stands, focusing on the poorest quality trees.

If however, the stand has been well managed in the past and is due for another thinning, the remaining trees should respond well to harvesting. These trees should have large healthy crowns to begin with and thinning will promote further crown and diameter growth.

Regardless of the level of past management, many mature stands would benefit from thinning. Thinning promotes regeneration and establishing a new generation of trees will benefit your sugar bush in the long run.

In some cases, managing stands with higher average diameters may have an adverse impact on sap production capacity. When you are determining how many trees to remove, be aware of the potential implications to your operation – if you suspect that it will dramatically reduce stand sap volume, thin conservatively and give the sugar bush ample time between harvests to adjust to the loss of taps. Over time, increases in tree health and growth can compensate the sugar bush operator for initial sap losses.

Regardless of the level of past management, many mature stands would benefit from thinning. Thinning promotes regeneration and establishing a new generation of trees will benefit your sugar bush in the long run.

Larger slow-growing or declining trees might be poor volume producers in the first place and their removal may not have that much of an impact on total sap volume.

Crop Tree Release in Uneven-aged Stands

When managing uneven-aged stands it is important to consider all diameters of trees when making management decisions. A prescription for an uneven-aged sugar bush will address this by recommending that the marker focus efforts on trees in specific size classes. For instance, if the sugar bush is overstocked in the polewood size class, the prescription will recommend the removal of more stems from this size class than from the others which are not overstocked. For this reason, the selection and release of crop trees is not as critical as it is for even-aged stands unless the particular size class is overstocked. However, crop trees should still be identified throughout the different size class categories and if possible released. If the stand is significantly overstocked (greater than 24 m^2/ha [105 sq.ft/ac] basal area) there should be ample opportunity to select and release crop trees. It is a good idea to identify potential crop trees from all diameter classes and not just those that need thinning.

Thinning the Sugar Bush: Long-Term Sustainability

The long-term sustainability of a sugar bush depends upon the continued establishment and success of Sugar Maple regeneration. Because of this, it is important to ensure that adequate openings in the upper canopy of the sugar bush are present. About 5% to 15% overall canopy openings scattered evenly throughout the stand are considered sufficient for maple regeneration. This level of canopy opening is also necessary to ensure enough space for the crop trees to have a good growth rate and productivity. Selecting individual trees among the closed canopy is the best method of achieving this goal – this is also called single tree selection.

Opening the stand up more than this, or creating too large of openings in the stand will encourage the establishment of other species

Establishment and Maintenance of Maple Orchards

Maple orchards are intensively managed maple trees that are grown at wide spacing with the objective of producing high volumes of sweet sap for maple syrup production. Most maple orchards in Ontario have been planted, but some have been developed from natural trees. Both Sugar Maple (*Acer saccharum Marsh.*) and Black Maple (*Acer nigrum Michx.*) are planted for maple orchards. Sugar Maple is much more abundant than Black Maple but both species are good sap producers and can be managed in maple orchards to produce high sap yields.

Autumn aerial view of Sanders maple orchard, near Finch in eastern Ontario

Many maple producers have learned through experience that open grown trees tapped along fencerows and roadsides produce sweeter sap than trees growing in a dense sugar bush. In addition to roadside plantings, some small maple orchards were established in farm fields. These orchards provide further evidence that high sap yields can be obtained from widely spaced, planted maples that develop deep, wide crowns.

Many farmers have land that is suitable for planting maples. Planting a maple orchard provides an opportunity to establish a new maple syrup operation or expand an existing one. Long-term planning considerations are important since the trees may not be large enough to tap for 25–30 years following planting. Some saplings may reach a tappable size of 25 cm (10 in) in diameter in about 20 years.

Maple orchards may be planted by using either seedlings or saplings. Seedlings selected for transplanting should be at least 60 cm (2 ft) high and up to 12 mm (1/2 in) in diameter. Saplings selected should be 1.2 to 3.0 m (4 to 10 ft) high and 12 to 25 mm (1/2 to 1 in) in diameter.

Most maple orchards in Ontario have been planted using vigorous sapling stock removed from openings in sugar bushes or their edges. The size of stock used often depends on what is available on the farm. Provided proper transplanting procedures are followed, successful maple orchards can be established with either seedlings or saplings.

Both roadside maples and field orchards offer excellent tapping opportunities.

Many maple producers have learned through experience that open grown trees tapped along fencerows and roadsides produce sweeter sap than trees growing in a dense sugar bush.

Benefits of a Maple Orchard

There are many benefits of growing a maple orchard. These benefits include:

- Improved land conservation, utilization, and aesthetics on the farm
- Expansion of an existing maple operation or initiation of a new one
- Improved sap productivity – more sap and sweeter sap
- Healthier, fast growing trees on good sites will reach tapping size in 25 to 30 years, some as early as 20 years after planting.
- Ideal sites for tubing and vacuum collection systems
- Tapholes in fast growing trees may close completely during the summer following tapping, especially if smaller diameter "health" spiles are used.
- Carefully selected and properly pruned trees are more likely to be strong structurally and less likely damaged by wind, ice or snow.
- Maple orchard trees develop wide crowns and a high live crown ratio (deep crowns) – tree crowns will have greater exposure to sunlight, contributing to sweeter sap.
- Improved sap production following selection and thinning promotes faster-growing orchards and should enhance profitability.
- Maple orchards are a lifetime investment since healthy trees should produce sap annually for over 100 years.

Planning for a Maple Orchard

Careful planning for a maple orchard is necessary to obtain maximum benefits from planting. The following should be considered as part of the planning process:

- ✔ Select the most suitable area for planting
- ✔ Prepare a map of the area to be planted
- ✔ Locate a good source of maple seedlings or saplings for transplanting
- ✔ Make plans for site preparation, planting and tending
- ✔ Consider provisions for adequate wind protection
- ✔ Consider protection from rodents, wildlife, livestock, insects and disease
- ✔ Consider providing for replacement of dead, dying, damaged or otherwise defective trees
- ✔ Be sure to seek the advice and assistance of a forester or maple producer with experience in maple orchards

Selecting a Maple Orchard Site

Good survival and growth of young transplanted maples depends in part on choosing a suitable site for the orchard. Sugar Maple grows best on deep, fertile, fresh, well-drained loam soils with a pH in the range of 5.5 to 7.5. It will grow on shallow, sandy, or clay soils but growth is slower and establishment is more difficult. Since rapid growth of the transplant maples is desirable, these sites are less suitable for maple orchards. Two factors are essential when choosing a site for a maple orchard: one is proximity to the existing sugar bush, and the other is how appropriate the soil and site type is for Sugar or Black Maple trees.

Location

Consider the following factors when choosing a site for a maple orchard:

- Proximity to existing sugar bush and sap processing operations
- Winter access to the site
- Economics of removing the field from the production of agricultural crops
- Protection from drying winds and other weather extremes

Soil and Site Type

Three factors are needed to evaluate soil and site for planting Sugar Maple trees:

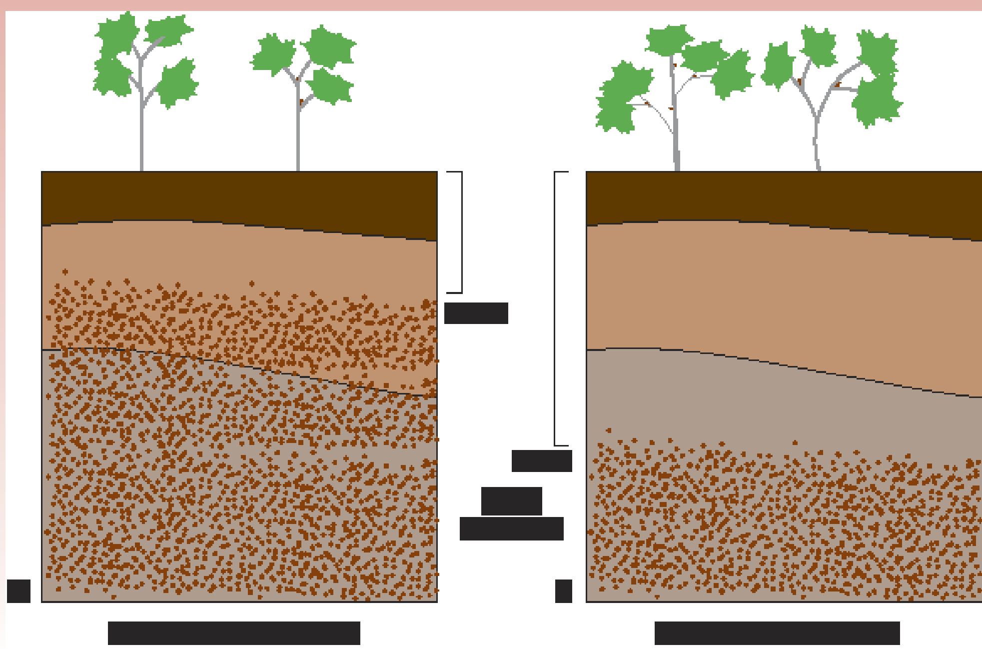
1. Depth to mottles
2. Soil texture class
3. Soil depth to bedrock.

To assess these factors, you need to dig a soil pit or use a soil auger to expose the soil profile. Dig a soil pit 120 cm (4 ft) deep in a site representative of the area in which you wish to work. If a site is highly variable, consider digging several pits.

Depth to Mottles

Mottles are rust coloured spots in the soil that mark the seasonal water table. Seasonal water tables are the depth to water in your soil in the wettest seasons of the year – spring and fall. Even if the soil is dry in July and August, seasonal flooding can kill water-intolerant trees such as Sugar Maple. Depth to the seasonal water table is important as it indicates the amount of water available for tree growth, and/or whether the site is too wet for some tree species. The higher the mottles are in the soil profile, the poorer the drainage of the site. Attempts to establish a maple orchard on poorly drained land will likely fail.

Figure 26: **The Impact of Seasonal Water Table on Long-term Health**



Knowing soil characteristics like depth to mottles is important before you establish your orchard. In Figure 26 for example, seedlings planted on the poorer site (A) will initially grow as well as those established on the better site (B). Over time however, the higher seasonal water table in A will eventually have an impact on the health and growth rate of the established orchard. Trees on site B will probably fair much better over the long run because the moisture regime of the site is more appropriate for Sugar Maple.

Soil Texture Class

An accurate determination of soil texture is an important step in determining whether Sugar Maple is a suitable species for the intended orchard location. Soil texture can be assessed in the field using a number of techniques. A thorough analysis of soil texture will include sampling from different soil horizons as well as checking a number of different locations throughout the planting area especially if the intended site is on a slope. Many farmers already know their broad textural groups; however, if you are unable to determine the soil texture of the site where you intend on establishing an orchard, inquire with your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs or the Ontario Ministry of Natural Resources for additional help.

Where soil depth to bedrock is shallow, the orchard trees will be more vulnerable to the damaging effects of very dry weather.

Soil Depth to Bedrock

Soil depth impacts soil water retention and rooting depth. Picture the soil as a sponge, the deeper (thicker) the sponge the more water it can hold/retain. In your pit, ensure that you distinguish between true bedrock and stones. Some sites may be too shallow to effectively plant trees. Soil depths less than 15 cm (6 in) over bedrock are not appropriate for any tree species. Depths from 15–30 cm (6–12 in) are not suitable for orchard establishment but may be planted with a suitable conifer species such as Jack Pine, which can act as a nurse crop for naturally regenerating maple. While soil depths between 30–60 cm (12–24 in) could be considered suitable for maple, soil depths greater than 60 cm (2 ft) are preferred, with the best depth being greater than 1 m (3 ft).

Other root restricting layers such as compacted soil can also impact tree growth. Compacted soil layers can occur naturally in soil, or they can result from poor farming practices such as tillage of fields while they are still saturated. Where possible, compacted layers in the soil profile should be corrected through deep plowing/ripping or the use of deep rooted forages, such as alfalfa.

Soil Moisture Regime

Moisture regime is defined as the capacity of a site to provide moisture to plants over the entire growing season. Factors which influence moisture regime are soil texture, depth to water table (mottles), slope and depth to bedrock. The following table summarizes moisture regime requirements of Sugar Maple.

Table 16: **Moisture Regime Requirements for Sugar Maple***

Soil Texture	Sloped Sites	Depth to water table (mottles)		
		60 to 120 cm (24–48 in)	5 to 60 cm (2–24 in)	< 5 cm (< 2 in)
Coarse sand and gravel	Dry	Fresh	Moist	
Sand	Fresh	Fresh	Moist	
Loam	Fresh	Fresh	Moist	
Clay	Fresh	Fresh	Moist	
Organic				Wet

Occurrence of maple on these sites:

Sugar Maple occasionally found
Preferred site for Sugar Maple
Sugar Maple seldom (if ever) found

Moisture Regime Definitions

Dry: Not enough moisture during parts of the growing season for optimum tree growth

Fresh: Optimum moisture conditions for tree growth throughout the growing season.

Moist: Too much moisture for optimum tree growth during some part of the growing season. Sugar Maple may survive but will develop a shallow rooting zone

Wet: Too much moisture for Sugar Maple root (tree) survival; Sugar Maple is seldom if ever found on these sites.

Evaluating the Site for Sugar Maple

By combining information on soil texture class, depth to mottles and soil depth to bedrock, it is possible to evaluate the suitability of Sugar Maple for any potential orchard site. Use the tables provided for the three examples (below) to assess the suitability of your particular orchard site. Please note that Table 17 applies to Site Region 6E while Table 17b is for Site Region 7E; a table for Site Region 5E has not yet been developed.

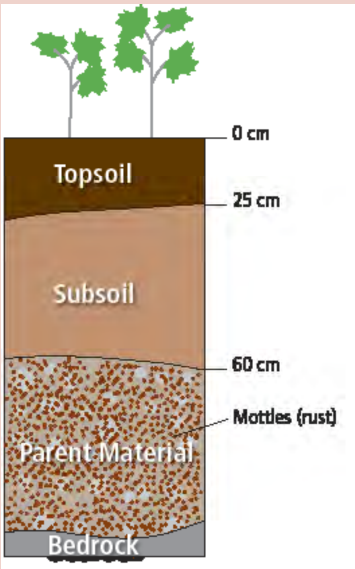
Example Site Type A

Texture class: Sandy
Depth to mottles: 60 cm (2 ft)
Soil depth over bedrock: >120 cm (4 ft)
Site Region: 6E

Is the site suitable? Table 17 below shows that it is a poor site for Sugar Maple. An alternative land use would be recommended.

Table 17: **Species Suitability – Region 6E***

Texture	**Depth to Mottles (cm)**						
	>150	100 - 150	80 - 100	50 - 80	30 - 50	15 - 30	<15
Very Gravelly	4	3	3	3	4		
Gravelly sandy	3	2	4	4	5		
Sandy	3	1	3	4	4		
Gravelly Loamy	3	3	3	2	4	5	
Coarse Loamy	3	1	2	2	3	5	
Silty	3	1	2	2	3	5	
Fine Loamy	2	1	2	3	3	5	
Clayey		4	2	4	5		



Best	1
Good	2
Moderate	3
Poor	4
Worst	5

Site Type B

Texture class: Silty
Depth to mottles: 55 cm
Soil depth over bedrock: <120 cm
Site Region: 6E

Is the site suitable? Table 17 illustrates that it is a good site for Sugar Maple. Establishing an orchard at this location would be recommended.

*Tables 16, 17, 17b: Adapted from *Guide to Species Suitability for Site Regions 6e and 7e - using field recognizable soil properties.* E.P Taylor and R.K. Jones. Addenda 1 to Ontario Institute of Pedology, University of Guelph

Table 17b: Species Suitability – Region 7E*

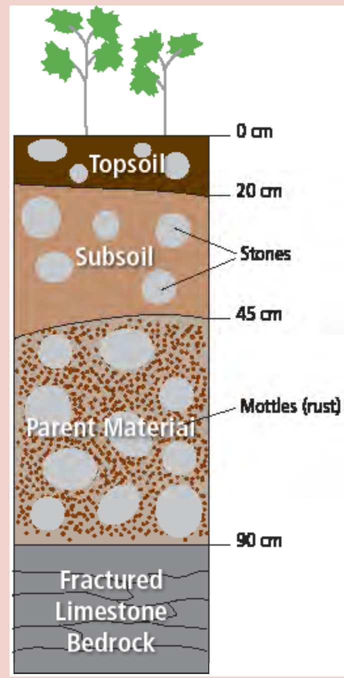
Texture	Depth to Mottles (cm)						
	>150	100–150	80–100	50–80	30–50	15–30	<15
Very Gravelly							
Gravelly sandy							
Sandy	3	2	2	4	5		
Gravelly Loamy	4	2	3	2	5	5	
Coarse Loamy	3	2	1	3	3	3	
Silty	2	1	1	2	2	3	
Fine Loamy	3	2	3	2	2	3	4
Clayey		2	1	2	2	3	4

Best	1
Good	2
Moderate	3
Poor	4
Worst	5

Site Type C

Texture class: Coarse loamy
Depth to mottles: 45 cm (18 in)
Soil depth over bedrock: 90 cm (3 ft)
Site Region: 7E

Is the site suitable? Table 17b indicates that it is a moderate site for Sugar Maple. If a better site could be found it should be considered, otherwise Sugar Maple could be tried on this site. Tile drainage or ditching could potentially lower the seasonal water table on this site, and would improve the site for Sugar Maple.



General Recommendations for an Orchard Site

- Do not plant in very dry or poorly drained soils.
- Avoid shallow soils as they are too dry for good growth.
- Poorly drained areas within orchards must be drained before planting Sugar or Black Maple. Red Maple or Silver Maple could be considered on these sites.
- Give consideration to providing for wind protection on the north and west sides of the orchard so wind speed and evaporation of moisture will be reduced. Ideally, a windbreak should be planted about five years before planting the maples. However, if this is not possible, plant the windbreak as soon as possible next to the orchard.

Good protection for this young maple orchard, located at the University of Guelph, Alfred Campus, is provided by the adjoining conifer plantation and hardwood woodlands.

Site Preparation and Tending

Competing vegetation is conrolled in bands across the site in this young maple orchard.

A commitment to site preparation and tending is critically important to the successful establishment of maple orchards. Best practices include:

- Approximately five years before planting, establish a windbreak on the north and west sides of unprotected orchard sites.
- A nurse crop of Christmas trees or other conifers could be planted in the orchard about five years before planting the maples to provide additional protection for them when they are set out. This is particularly advantageous on dry or exposed sites. Shade from nurse crop conifers will help prevent sunscald damage on the young maples.
- Control grass and weeds before any planting is carried out, including nurse crops. This can be accomplished by cultivation or with the use of herbicides.
- Ploughing, discing, and/or cultivating the site the year before planting commences is recommended where soil conditions permit. If the site is not completely prepared, 1.2–1.8 m (4–6 ft) strips should be prepared for setting out the transplants.
- Continue cultivation between the rows for three to five years after planting the maples. By then the transplants should have reached a 'free-to-grow' status and be free of competition from grass and weeds.
- Continue control of grass and weeds with herbicides by spot or band spraying herbicides the year before the maples are planted. This can be done either by controlling grass and weeds in a 0.9–1.2 m (3–4 ft) circle around each tree, or in a 1.2–1.8 m (4–6 ft) strip or band past each tree.
- Continue control of grass and weeds near the trees should be continued in the orchard until the maples have reached free-to-grow status.
- Establish a ground cover crop such as clover or a grass legume mixture when the control of grass and weeds is no longer feasible.
- Don't mow the grass and weeds during the summer months on dry sites. Mow in the fall so the habitat for rodents will be removed. Be very careful not to damage the maple trees with machinery when tending the orchard.

Orchard Design and Spacing

This maple orchard, located at the University of Guelph, Kemptville Campus, was established with a 6.5 m x 6.5 m spacing.

Maple orchards should be designed to provide adequate space for the development of deep and wide crowns of the planted trees and to facilitate access for extensive operations. Management considerations should include:

- Space single-row plantings, or maintain fence row and roadside trees about 9.1–12.2 m (30–40 ft) apart.
- Initial spacing for a maple orchard may vary depending on the management objectives. A desirable spacing is 6.5 m by 6.5 m (21 ft by 21 ft) or 250 trees/ha (100 trees/ac). Wider spacings (i.e. 9–12 m or 30–40 ft) may be used where intercropping

is incorporated into the design. Closer spacings (i.e. 4.5 m or 15 ft) may be used to minimize re-planting requirements due to mortality and to provide more opportunity to select high quality crop trees during thinning operations.

- The maples may be intercropped in their developing years with Christmas trees or ornamental conifers between the rows. Remove these trees once they begin to interfere with crown development of the maples.

Transplant Stock

A successful maple orchard can be established using either maple seedlings or larger saplings.

Maple seedlings may be selected and transplanted as bare root transplants. Most maple orchards in Ontario have been planted with maple saplings transplanted from nearby woodlots. The transplants are moved with a large root ball, which protects the roots. Use of local saplings ensures that the planted trees are genetically adapted to the area.

Most maple orchards in Ontario have been planted with maple saplings transplanted from nearby woodlots.

Vigorous maple seedings in a managed sugar bush

Transplanting Maple Saplings

Maple seedlings can be lifted from openings in sugar bushes, windbreaks and fence rows or they can also be purchased from some commercial nurseries.

Best practices include:

- Planting saplings originating from trees growing in the same seed zone as the orchard. For more information check out the Forest Gene Conservation Association at www.fgca.net
- Planting large stock, at least 60 cm (2 ft) high if nursery seedings and at least 120 cm (4 ft) if natural saplings
- Making sure the roots of transplanted trees are kept moist and shaded from sunlight
- Planting as soon as possible after lifting

a) When to Transplant

- For best results, young maple trees should be transplanted in the spring as soon as the frost is out of the ground. All transplanting should be completed before the buds begin to burst. Maple trees can also be transplanted in the fall after the leaves have dropped.

b) Tree Selection

Guidelines for the selection of planting stock include:

- Choose either Sugar Maple or Black Maple.
- Choose trees for transplanting from areas near the orchard site to ensure that stock is well adapted to local climatic conditions.
- Select and tag trees well in advance of transplanting. If saplings are selected the summer before transplanting, leaf condition, as well as bark and stem condition, can be assessed. Also it is easy to identify Sugar Maple from Black Maple by leaf characteristics.
- The sugar content of young Sugar Maple saplings can vary considerably. Ideally only saplings with the sweetest sap should be transplanted. However, since tree age and environmental factors also influence sap

sweetness, most producers do not feel it necessary to determine sap sugar content at this time. That will be done when thinning the orchard at a later date.

- Select open grown trees or trees growing at the edge of the sugar bush: these trees are used to full sunlight conditions. Also select fast growing trees from openings in the sugar bush made in previous thinnings. It is very important to transplant only healthy, young, fast growing trees since survival and growth of these trees will be superior to older, suppressed trees that have been removed from shady, overcrowded woodlots. Also the incidence of sunscald damage is minimized if fast growing trees are transplanted.
- Select straight, vigorous trees that are free of major stem defects and disease.
- Choose saplings ranging in diameter from 12–25 mm (.5–1 in) which are from 1.2–3.0 m (4–10 ft) in height. Saplings in this size range can be dug and transplanted manually or mechanically.
- Select fast growing trees showing growth on the leader of at least 30 cm (1 ft) per year. Flat top trees or those without a central leader are less desirable. Slow growing trees should be avoided.

c) Digging Maple Saplings for Transplanting

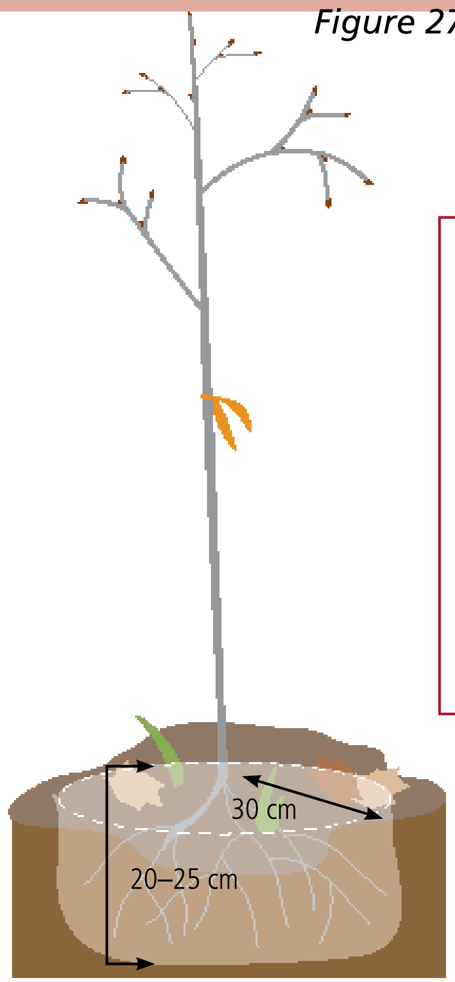
Digging maples for transplanting should be carried out in the spring (before leaves emerge) or fall (after leaves drop) when the soil is moist.

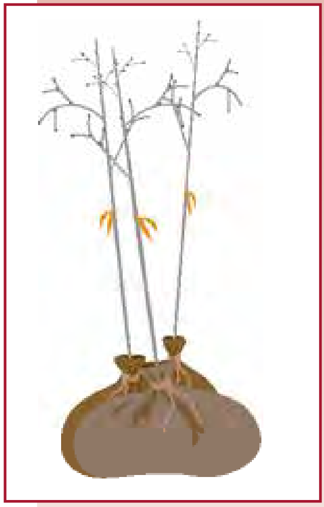
- Prepare the tree for lifting by driving a spade or shovel into the ground about 20–25 cm (8–10 in) deep in a circle 30 cm (1 ft) from the stem of the tree. This will sever the longer, larger roots running away from the base of the tree.
- Work the spade or shovel downwards and inwards to loosen the root ball for lifting.
- Using a spade or shovel, lift the tree, being careful not to let the soil fall off the roots. If the soil falls off the roots, try to replace it, or keep the exposed roots moist and covered until transplanted. This can be done by wrapping the exposed roots in wet burlap.
- Wrap the roots and earth (root ball) in burlap to hold the soil on the roots. Tie the burlap securely around the base of the stem.
- The tree is now ready for moving to the planting site. Avoid delays in doing this. To avoid drying, plant the same day.

When maples larger than 2.5 cm (1 in) in diameter are transplanted, a larger ball of earth should be taken with the tree in order to ensure successful transplanting. Trenching to provide for removal of the root ball is necessary. It is generally recommended that the root ball be 30 cm (1 ft) in radius for each 2.5 cm (1 in) in diameter of the stem for trees from 2.5–7.6 cm (1–3 in) in diameter. Front-end loaders on farm tractors or a backhoe are useful for lifting and moving larger saplings.

It is generally recommended that the root ball be 30 cm (1 ft) in radius for each 2.5 cm (1 in) in diameter of the stem for trees from 2.5-7.6 cm (1-3 in) in diameter.

Figure 27: **Digging Saplings**





It is not usually necessary to water trees during periods with normal precipitation except for the first few years on dry sites. Overwatering forces oxygen from the soil needed for root development.

d) Planting Procedure

- Dig planting holes large enough to accommodate the root ball.
- Place the root ball in the hole and untie the burlap. It is not necessary to remove the burlap unless it is to be used again.
- The planting hole should be deep enough so the tree will be planted at the same level in the soil as it was previously.
- Replace earth to fill in the area around the perimeter of the root ball and pack firmly with the heel. Then, add water to settle the soil further and eliminate air pockets. After the water has drained, fill the hole around the perimeter of the root ball so the soil is level with the root collar, packing again with the heel.
- Maintain the orchard density after planting by replacing dying or dead trees, at least during the five years following planting.

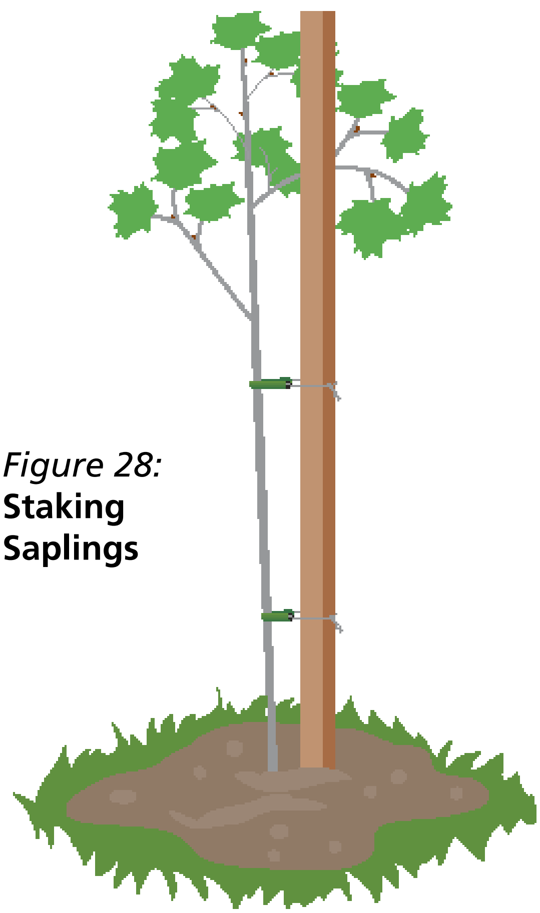


Figure 28: **Staking Saplings**

Orchard Maintenance

a) Watering

- Water thoroughly when the tree is planted. Further watering is not normally required until the leaves begin to emerge.
- Maples transplanted in the fall require little additional water at least until the new leaves begin to emerge the following spring.
- Water trees during dry periods for several years after planting.
- It is not usually necessary to water trees during periods with normal precipitation except for the first few years on dry sites. Overwatering forces oxygen from the soil needed for root development.
- Trees watered with a pail should receive 2 or 3 full pails at a time so the water will soak into the roots completely.
- Mulch trees to help reduce soil moisture loss if they do not receive sufficient moisture.

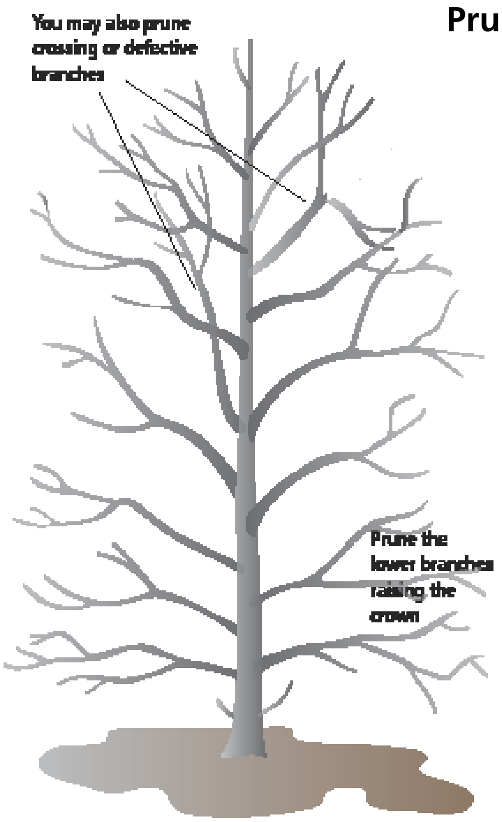
b) Staking

- Stake newly planted maple saplings to give artificial support and prevent excessive swaying and breakage. A strong stake, 1.8–2.4 m (6–8 ft) in length, should be driven into the ground near the base of the tree. Secure the tree to the stake using a short length of garden hose with a wire running through it. The garden hose will protect the bark from damage. The stake should be retained for several years until the tree is structurally sound.

c) Pruning

- Prune the tops of the transplants to compensate for the loss of roots and to maintain a more favourable balance between the roots and crown. Prune to reduce the leaf area and transpiration of water from the tree.
- Avoid loss of sap by pruning after transplanting when the new leaves are only partly formed.
- Prune so side branches are not cut back more than about one third. Less pruning is needed on smaller saplings when most of the roots have been saved during digging or when the crown is sparse.
- Do not cut the leader.
- Remove one leader when a tree has acute forking and a double leader.

Figures 29, 30: Pruning

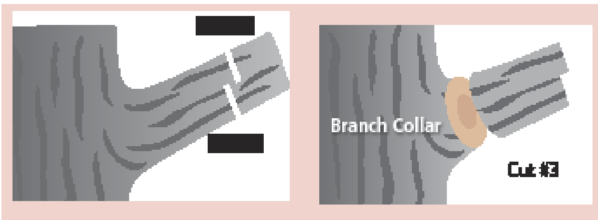


Pruning lower branches every two years helps avoid any large branches in the tapping zone.

- Remove some of the lowest, extended branches in the spring following transplanting. In the first year, it is not usually necessary to completely remove other branches of the tree unless they are damaged or defective.
- In following years, remove up to 3 lower branches every 2 years to a height of 3–5 m (10–16 ft). It is important to avoid large branches in the tapping zone of mature trees.
- Pruning is best carried out when trees are dormant and not actively growing

As the orchard develops, it will be necessary to remove other lower branches to provide space for moving around under the trees when tapping and collecting sap. A live crown ratio of 2/3 is desirable.

Corrective pruning for damaged, diseased or defective branches will be necessary as the orchard develops.



d) Fertilization

- For best growth, fertilizer should be used, but not at planting time.
- Normally, a dry commercial fertilizer should not be used until new roots are established and can absorb it. Therefore it is best to wait until the end of the first growing season or the beginning of the next growing season the following spring to apply.
- The fertilizer should be spread on the ground near the perimeter of the planting hole.
- It is recommended that a balanced fertilizer such as a 10-10-10 be used.
- Well-rotted barnyard manure applied in the early spring following transplanting would be beneficial if commercial fertilizers are not used.

When pruning, it is important to avoid the development of large branches in the tapping zone of mature trees.

Thinning could be as early as 30 years, which is shortly after tapping of some of the trees commences.

Thinning the Maple Orchard

- After crown closure has occurred, maple orchards will need to be thinned to remove inferior, defective, and less sweet trees and to improve growth rates. This will increase the potential sap yield and quality of the orchard.
- Thinning a maple orchard should normally commence when the tree crowns become crowded and the diameter growth of the bole slows down significantly.
- Timing for the first thinning is dictated by growth characteristics of the trees. Thinning could be as early as 30 years, which is shortly after tapping of some of the trees commences.
- Before thinning commences, test the sap sweetness of each tree for at least two to three years. Good quality trees with the highest average sugar content should be selected and identified with a spot of tree marking paint. Keep sap sweetness records for future use.
- Other factors to consider when thinning are:
  - Tree-health
  - Tree branching habit or structure
  - Tree location (border trees can be left closer together)
- The orchard should be gradually, selectively thinned to 86 to 111 trees per hectare (35 to 45 trees per acre) over a period of many years following the first thinning.

Protection from Livestock and Wildlife Damage

Do not graze livestock in maple orchards. They will browse on maple saplings, often destroying them. Damage to maple orchards may be caused by several wild animals. Mice, voles, rabbits, groundhogs and deer can all cause significant damage to orchard trees.

- Deer can destroy maple seedlings and saplings or seriously damage them when browsing on them. They can also damage the bark of saplings by rubbing their antlers on the stem of young trees. It is not wise to plant maple orchards when the deer population is high unless adequate fencing is installed to keep them out. The Ontario Ministry of Agriculture, Food and Rural Affairs and the Ontario Ministry of Natural Resources have a joint publication available on deer management entitled *Deer Control Practices in Agriculture*. This publication contains details on fencing.
- Rabbits may cause damage to maple trees in the winter as their main food sources become scarce. Rabbits feed on the bark, causing significant injury to the tree. Commercial rabbit repellents are available. They are applied to the bark of the tree in early fall. When they are used, be sure to follow manufacturers' instructions and treat the tree as high as rabbits can reach when standing on deep snow. Tree guards, wire netting or aluminium foil placed around the lower portion of the stem are also used to protect trees from damage by rabbits. Plastic guards should be removed during the growing season.

Plastic guards offer some protection from wildlife. They should be removed during the growing season.

- Groundhogs or woodchucks can cause damage to trees in maple orchards during the spring, summer and fall. They damage the bark by gnawing, teeth sharpening, or tree climbing and damage roots when burrowing. Commercial fumigants, trapping and shooting are measures used to keep groundhogs under control.
- Vole control is important since they can cause serious damage to the bark of the trunk and roots by feeding on them in the winter under the snow when their normal food supply is low.

Several control methods can be applied to control the vole population and reduce damage.

- In the fall remove grass and weed cover in the orchard by cultivation, use of herbicides or mowing.
- Close mowing of ground cover crops will help discourage voles.
- Use of tree guards and shelters will protect trees from vole damage. Make sure they are firmly anchored in the soil.

The image above shows the use of plastic mulch and tubex shelters in the McCutcheon maple orchard near Coldwater, Ontario.

Tractor maintenance in the Brouwer Maple Orchard near Aylmer, Ontario

The *Maple Orchard Directory,* which was published in 2000, is available from the Promotion Store of the Ontario Maple Syrup Producers Association, www.ontariomaple.com. This Directory includes inventory information and recommendations from over 20 maple orchard growers in Ontario. It provides an important link to fellow orchard growers and is an excellent reference for those considering the establishment of their own maple orchard.

8 Tapping Your Sugar Bush

While Sugar Maple has a strong ability to compartmentalize wounds, improper tapping can overcome natural defense barriers, leading to more extensive staining and decay.

Maple sap is transported up and down the tree through a network of specialized cells found in the first few centimetres (inches) of wood just below the bark. Drilling a hole in the tree each spring severs these cells, allowing sap to flow out of the tree when conditions are favourable (see 'Sap Flow Mechanism', page 83). A taphole is a type of wound and the tree reacts to it just as it would if a branch were broken or cut off. Soon after the hole is drilled, the tree begins to 'wall off' the wound isolating it from the rest of the tree through a process known as compartmentalization. If the tapping is done properly, internal damage is minimized and the tree can be tapped year after year for decades. Many sugar bush operations proudly display cross sections of trees showing old tap hole scars which go back 50, 75 even 100 years. These scars provide a historical record of the tapping practices within the sugar bush. The maples' cross section clearly demonstrates the long-term potential for sap production and often becomes a focal point for visitors to the sugar camp.

Old tap holes eventually heal over and are buried in the tree as it continues to grow in diameter.

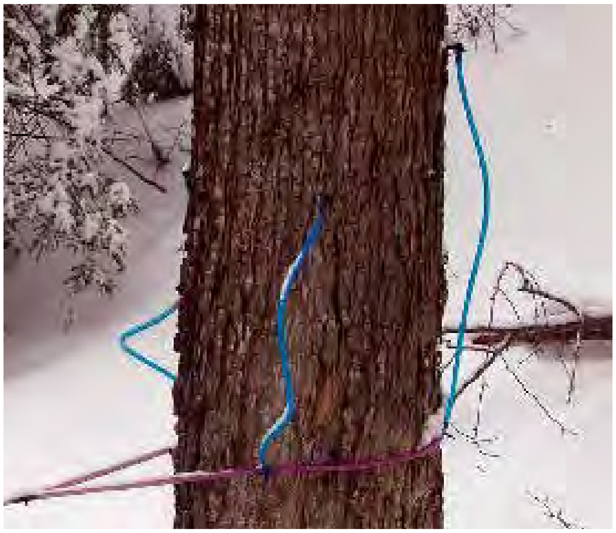
The Process of Compartmentalization

When trees are tapped, the living cells in the wood begin to respond in ways that protect the tree. Substances are produced which limit the entrance of air and disease causing microorganisms. These changes, together with alterations in the new cells produced by the cambium after the wound is made, create barriers that effectively compartmentalize or wall off the injured area in healthy trees. The faster this happens, the sooner wounds become unsuitable for infection by discolouration and decay fungi. Even when compartmentalization is effective, zones of discolouration occur for some distance above and below the tapholes.

Tapping Practices

Poor tapping practices can have a serious impact on tree health. Tap holes which are too close together often have stain columns which join together to create a large zone of discolourization. While Sugar Maple has a strong ability to compartmentalize wounds, improper tapping can overcome natural defense barriers, leading to more extensive staining and decay.

In vigorous trees, discolouration of wood is limited to a streak about 1.25 cm (0.5 in) wide and up to about 46 cm (18 in) above and below the taphole. Tapholes in vigorous trees usually heal over in 2 to 3 years.



Too many tap holes or tap holes close together can have a negative impact on tree health and productivity. The tree above demonstrates good spacing and the recommended spiral tapping pattern.

Spiles can become embedded in healing bark if not removed from the tree: they should be removed as soon as sap collection is completed each year.

Spile Design

There have been a number of new and innovative spile sizes and designs available for sale to syrup producers. In particular, two smaller diameter spiles (19/64" and 5/16"), have been shown to have significant benefits for maple operations. Research has shown that tapholes associated with the use of these spiles heal more quickly and have a smaller zone of discolouration than those of the traditional large spiles. Research in both Canada and the United States has shown that sap yields using these spiles under vacuum were comparable to that of traditional spiles. Sap yields may be reduced to some extent with gravity installations.

While it may seem like a good idea to continue reducing spile sizes in order to lessen the potential impact on the tree, limited research results have indicated that the use of spiles smaller than 19/64 of an inch has been shown to reduce sap flow especially during peak flows. If you are considering using a new type of spile check to see that the design has been independently tested and researched in the field and that any possible effects on sap yield are acceptable for your operation.

Smaller modern spiles have a lesser impact on tree health. Inset: comparison between a regular 7/16" spile, and a 5/16" 'health' spile

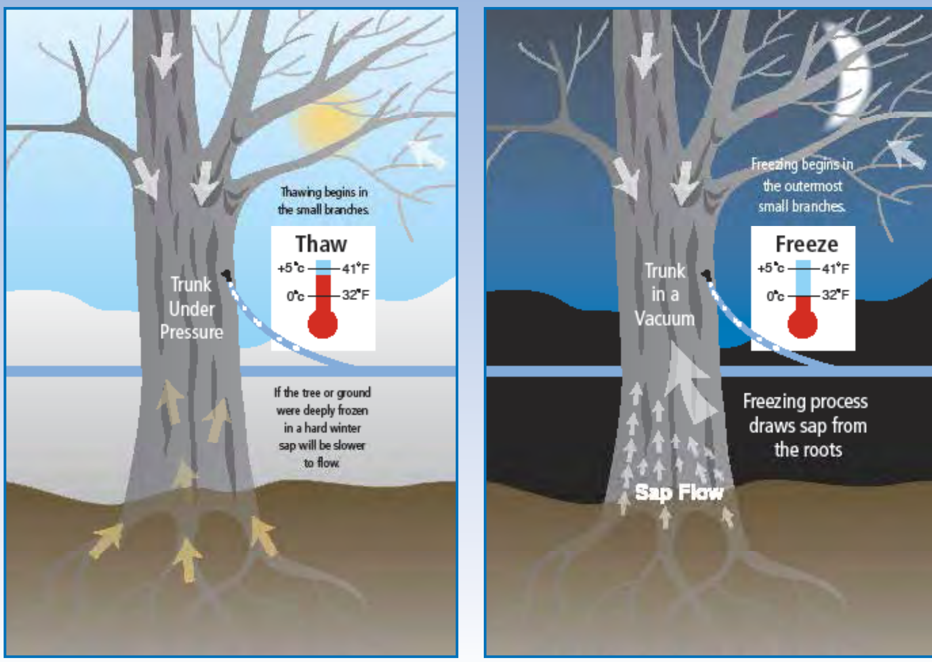
Sap Flow Mechanism

The freezing process begins in the outermost small branches and progresses inward toward the trunk and downward toward the roots. This is essentially a twig to trunk and top to bottom process. Provided the roots are not frozen, this draws sap up from them all the way to the tips of the branches and progresses downward as the freezing progresses to larger and larger branches. This is why a slow freezing process moves more sap up the tree. In this circumstance, there is increased time for the sap to be pulled up by the freezing process and more complete filling of the fibrous cells around the xylem vessels.

The thawing process that releases the sap under pressure progresses essentially the same way as the freezing process, with the tips of the branches thawing first and then progressing down the larger branches toward the trunk and down the trunk to the roots. As the thaw progresses, the sap flow will usually start at the branch tips and move progressively inward toward the trunk and down the trunk to the base of the tree (see Fig 31, p 80).

Sap Flow Mechanism

Figure 31: **Sap Flow Mechanism**



Sometimes the sap won't flow even though the air temperature appears to be ideal. Prolonged periods of cold weather can freeze the sapwood delaying sap flow until the tree thaws.

Factors which Influence Sap Flow

Sap flow is highly variable and influenced by a number of inter-related factors. Some of these are:

1. **Temperature change:** This is by far the most important factor. Good sap runs normally occur when the day time temperature rises to about 5°C (45°F) following a frosty night where the temperature drops just below freezing -5°C (23°F). Extremes in temperature changes have a negative impact on sap flow.
2. **Geographic location:** Some areas of Ontario have historically higher sap flows. This may be a function of temperature but it probably involves a number of factors.
3. **Location in the Sugar Bush:** There can be considerable variability within a sugar bush.
4. **Crown Size:** Trees with larger crowns tend to produce more.
5. **Aspect:** The direction the land is sloping has been recognized as a factor influencing sap flow. Sugar bushes on eastern or southern facing slopes are more exposed to the sun and, as a result, tend to start running a little earlier in the season when temperatures are generally more ideal for sap flow. Sugar bushes on other slopes tend to start later but may run somewhat longer.
6. **Tree Age, Health and Growth:** Variation in sap production exists among individual trees depending on age and growth rate. Healthy trees tend to produce more sap than unhealthy ones. Vigorous trees can put on more new wood than non-vigorous ones; this means that there is less chance you will be drilling into stained wood. On very old trees which have slowed in growth, it is sometimes hard to find new wood to drill into.
7. **Sap Collection Systems:** Research has demonstrated that sugar bushes on vacuum tend to yield more sap volume than those using buckets.

Tapping Practices for Maximum Sap Flow

The following guidelines will help maximize sap productivity while maintaining tree health:

- Tap early enough in the late winter or early spring to ensure that the first good runs of sap are obtained
- Tap trees when the temperatures are near freezing or above freezing to reduce the incidence of cambial damage, -5ºC (23ºF) or warmer
- Use an appropriate drill bit (see below) to minimize the potential for frost cracking (inset) and cambial damage if the wood is frozen when the trees are tapped.

Inset: Frost crack extending from taphole

- Tamp spouts in gently to avoid splitting the bark (inset), which causes increased damage to the tree; the health spout is designed not to require tamping and may normally be turned in until it is seated properly
- Use sharp drill bits that will cut clean edged holes
- Tapholes should be drilled at a slightly upward angle of about 10 degrees to facilitate sap drainage
- Tap on all sides of the tree to space out tapholes
- Tap only in healthy, white sapwood
- Locate new tapholes 15–20 cm (6–8 in) from old tapholes in a horizontal plane and 30 cm (12 in) or more in a vertical plane to avoid tapping into unproductive, stained wood
- Do not tap deeper than 5 cm (2 in) into the sapwood; stop drilling if stained wood is reached
- Do not use chemicals in the tapholes (e.g., paraformaldehyde, alcohol or chlorine)
- Ensure that spouts are thoroughly rinsed if treated with chemicals
- Limit the number of taps per tree to what is recommended in the tapping guidelines for healthy and stressed trees and/or slow growing trees
- Do not tap trees with a diameter less than 25 cm (10 in) at 1.3 m (4.5 ft) above ground
- On vacuum systems or where sap yield is a secondary objective, use the 19/64 inch or 5/16 inch spout

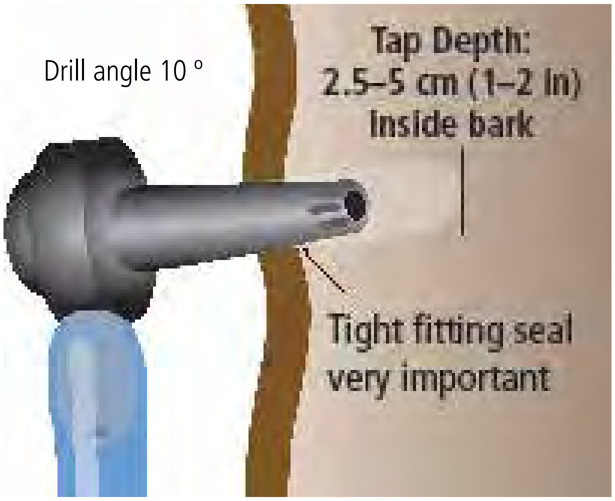


Figure 32: **Tap Depth**

It is important to install each tap properly. Having a tight seal is critical for maximizing the sap volume collected. Check your taps and tubing systems periodically throughout the season.

In Ontario, there are two recognized guidelines for determining the number of tapholes per tree: one for tapping healthy vigorous trees and another for tapping unhealthy or stressed trees.

Tapping Guidelines in Ontario

In Ontario, there are two recognized guidelines for determining the number of tapholes per tree: one for tapping healthy vigorous trees and another for tapping unhealthy or stressed trees. It is important to evaluate each tree in the sugar bush before it is tapped to adequately determine the recommended number of taps. Both these guidelines were developed for the traditional 7/16 inch spile but this does not mean that they should be altered just because you are using a new type of spile. Research has not been conducted on altering the number of taps or the minimum tappable diameter of trees for smaller spiles. It is strongly recommended that you follow the appropriate tapping guidelines regardless of the type of spile you are using, in order to better safeguard the long-term health of the tree.

Tapping Guidelines for Healthy Trees

Some important characteristics of healthy trees are:

- Rapid diameter growth rate
- Trees which are not suppressed by competition
- Trees with full crowns, without dieback
- Trees not under stress due to the effects of insects, disease, storm damage or drought
- No or very few indicators of stem/branch damage or internal decay (fungal conks on the stem)

Table 18: **Tapping Guidelines for Healthy Trees (Chapeskie, 2003)**

Diameter of tree measured outside bark at breast height (4.5 ft above ground)	Number of tap holes per tree
Less than 25 cm (10")	0
25 cm (10") to 36 cm (14")	1
37 cm (15") to 49 cm (19")	2
50 cm (20") and larger	3

Earlier tapping guidelines in Ontario recommended up to four taps per tree on larger trees. Some maple producers may decide to place more than three taps per tree on very large trees greater than 63 cm (> 25 in) provided these trees are in very good overall health. In recent years, however, most commercial maple producers are restricting the number of taps per tree to three or less.

The Conservative Tapping Guideline for Stressed or Slow Growing Trees

Some characteristics of stressed and/or slow growing trees are:

- Slow diameter growth rate
- Very old trees
- Slower than normal tap hole closure (greater than 3 years)
- Crown dieback
- Bark is indicative of low vigour
- Trees severely damaged by ice or wind
- Mechanical damage to the bole of the tree
- Signs of internal decay (i.e. fungal conks on the bole of the tree)
- Heavy insect defoliation

Table 19: **Conservative Tapping Guidelines for Stressed or Damaged Trees (Chapeskie, 2003)**

Diameter of tree measured outside bark at breast height (4.5 ft above ground)	Number of tap holes per tree
Less than 25 cm (12")	0
25 cm (12") to 44 cm (17")	1
45 cm (18") and greater	2

Large tree tapped with 2 health spiles

Sap Collection Systems and Access Roads

The use of plastic tubing systems to collect sap has increased due to the amount of labour required for bucket or pail installations as well as technological innovations which have resulted in more durable and potentially more productive tubing collection systems.

Road and trail systems should be designed to minimize site disturbance and tree damage and still allow for efficient sap collection and transfer. Soils are normally saturated during the production season and there is potential for soil compaction and rutting if care is not exercised.

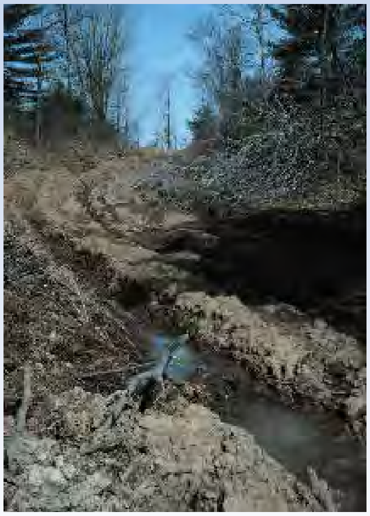
Tubing systems normally result in less mechanical damage to roots and the lower stems of trees than bucket collection systems since the need for access to collect and haul sap is minimized. Regardless of the sap collection system used, the amount of traffic in the sugar bush should be minimized to what is necessary to facilitate sap collection activities. The use of high flotation equipment in sap collection activities is also strongly encouraged.

Some maple producers bury mainlines to limit above ground obstructions. This practice can negatively affect the long-term health of maple crop trees located in proximity to the lines. With this practice, some damage to the root

Sap Collection Systems

Top left: Buckets on a roadside tree

Top right: Lateral tubing in sugar bush



Bottom, far left: Gravel road through sugar bush

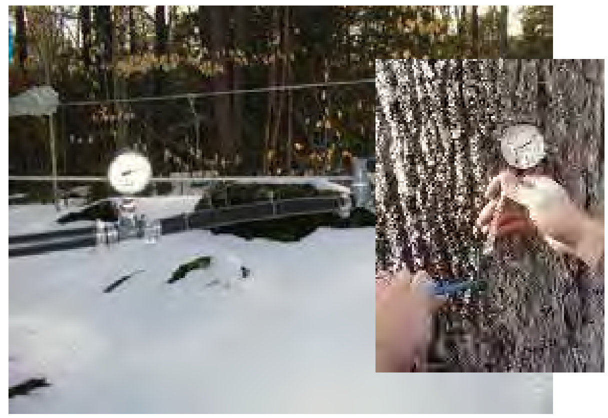
Bottom, left: Severe rutting in access road

Above: Lateral lines connected to buried mainline in sugar bush systems of crop trees is unavoidable and will provide infection courts for decay fungi. Over time, this could lead to decline or even some mortality of crop trees growing in proximity to the buried lines. In 2005, research designed to assess potential long-term negative effects of burying mainlines on the health of maple crop trees was implemented in Ontario. The results of this research have been summarized in a technical report.

When possible, maple crop trees and potential crop trees should not be used to support maple tubing systems. If this is necessary, the supports should be flexible and have a rubber sleeve which reduces the potential for in-growth of the supporting wires into the tree and associated damage. Even the sleeves should be adjusted periodically to avoid any negative impact on the trees. It is much preferable that non-crop trees and artificial supports be used for line supports.

Tubing installation with side wire support

Research and operational experience have demonstrated that proper application of vacuum to tubing systems can substantially enhance sap yields, particularly when the weather pattern is not conducive to good sap flow. Research has shown that levels of vacuum at the tree of 18–20 in. of mercury or even higher do not negatively impact the health of the trees.



Vacuum guages

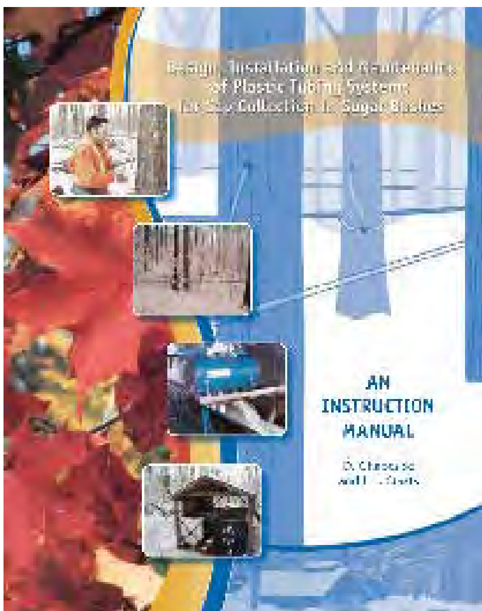
There is a strong trend in the industry towards the installation of permanent tubing systems where both mainline and lateral lines are left in the sugar bush year round. Floating installations where mainlines are anchored from both sides at intervals are becoming increasingly popular because they are easier to install and maintain than more rigid installation with in-line supports such as pickets or posts. Where this type of installation is used, the position and slope of the mainline can be easily restored if a branch were to fall on the line. Also, the mainline can be easily taken down to facilitate thinning and harvest operations and then restored after these activities have been completed.

For permanent tubing installations, it is recommended that the installation be replaced on a cycle similar to that used for thinning the sugar bush (10–15 years). After the thinning operation has been carried out, perhaps in stages, a new tubing system can be installed which incorporates the latest research innovations.

Chemicals accepted for tubing maintenance operations, such as chlorine, should not be discarded in the sugar bush.

Operator safety should always be foremost in mind when working around sap collection installations.

Other up-to-date detailed references regarding relevant considerations related to tubing installation are planned for publication in 2006. These include an Ontario publication entitled *Installation, Operation and Maintenance of Plastic Tubing Systems for Sap Collection in Sugar Bushes* and the revised *North American Maple Syrup Producers' Manual*.



9 Problems Which Affect Sugar Bush Health and Productivity

Throughout its life, every tree is subject to many factors which have either a positive or a negative impact on its health.

Throughout this manual, we have talked about improving sugar bush health and productivity through good management practices. While proper planning, tapping and harvesting practices are useful tools for achieving improved health and productivity, it is important to recognize that there are many factors which can have a long-term negative impact on your sugar bush. Some of these factors are in your control to avoid and some are not. However, even though some factors are unavoidable and will have a significant impact on health and consequently, productivity, the well-managed sugar bush has a much better chance of weathering the impacts of these factors.

Your sugar bush is in a constant state of change – the trees grow, reproduce and eventually die from a wide number of causes. Throughout its life, every tree is subject to many factors which have either a positive or a negative impact on its health. For example, consider two trees in close proximity to one another which are competing for resources in an overcrowded woodland. If an infestation of caterpillars kills one of the trees while the other is able to recover, it could be said that the remaining tree has benefited from the caterpillar outbreak. The surviving tree might recover and be able to capitalize on the increased light and space by actually growing faster and being healthier than before. Sugar bush management is geared at doing roughly the same thing, but under controlled conditions. Unfortunately however, nature has its own way of influencing management efforts and it is important to be aware of the potential impacts of insects, disease, storms and dry weather on sugar bush productivity.

Background: Trees defoliated by forest pests

Overcrowding, insects, weather and human activities as well as a host of other factors, can cause varying amounts of stress which affects growth and ultimately productivity.

Top image: Aerial view of the effects of drought in Ontario forests.

Porcupine damage

Managing Stressed Sugar Bushes

Trees, like people, suffer from and react to stress. Overcrowding, insects, weather and human activities as well as a host of other factors, can cause varying levels of stress, affecting growth and ultimately productivity. Understanding how these stressors interact and what the potential impacts might be, is key to knowing what is needed for maintaining a healthy and productive sugar bush. In general, younger trees are less susceptible to stress influences and can recover more quickly than older trees. Healthy Sugar Maple trees tend to be fairly resilient when faced with adverse conditions and in many cases no action is needed. However, some stress factors can weaken a tree making it vulnerable to other secondary factors. Under these circumstances, corrective management may be warranted in order to reduce any adverse effects on productivity caused by tree loss or decline.

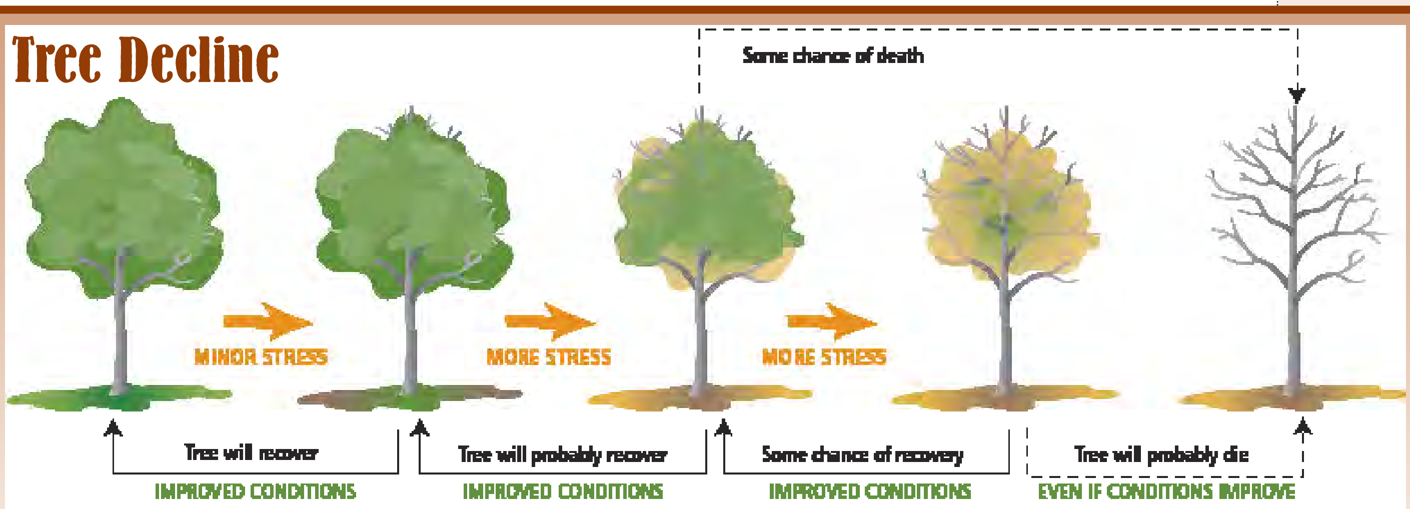


Figure 33: **Tree Decline** *Every tree has the capacity to handle some stress and can usually make a full recovery once the stress has been alleviated. Some trees however, decline to the point where they can not recover even if the stress is reduced.*

Key Factors in Maintaining a Healthy Woodland

- Maintain biodiversity to the extent possible.
- Operate carefully so as to minimize any negative impacts such as tree damage or soil compaction.
- If your sugar bush is severely stressed, reduce the intensity of tapping and re-evaluate any plans you have for harvesting.
- Identify any stress factor(s) as best you can and determine what corrective action may be required.
- Do not overreact – if you can not determine what needs to be done seek the advice of a professional and do not harvest trees simply because they are stressed.
- Do not use crop trees to support mainlines without effective guards to protect the trees from damage as they grow.
- Before burying main lines in the bush, consider the amount of root damage that will be done. Root damage could seriously affect the overall health and vigour of the trees and possibly introduce future root decay problems into the stand.
- Do not allow cattle grazing in the sugar bush. Cattle damage tree roots, compact the soil and alter natural vegetation.
- Monitor your sugar bush regularly for emerging health issues.

- Restrict traffic in the sugar bush to a minimum, particularly when soils are wet. This prevents soil compaction and root damage. Consider using pipeline as opposed to buckets to further minimize traffic.
- Try to use less damaging machinery, for example, an ATV instead of a tractor.
- Carefully plan all roads to limit changes in natural drainage patterns.

Taking Remedial Action to Reduce Stress

Direct action may be needed to help alleviate specific sugar bush stress factors. Some of these include:

- The use of insecticidal sprays or biological control agents to help control caterpillar infestations; it is recommended that you check with an experienced professional before using pesticides
- The removal of diseased trees from the sugar bush to reduce the risk of infection to other trees; removal is particularly important if trees are stressed from other damaging factors
- Fertilization or liming may be carried out to correct deficiencies or imbalances in the soil that are affecting tree health and productivity. Remember to do a foliar and/ or soil test first (see page 91).)
- Improving drainage within the stand or diverting water sources will help with seasonal flooding.
- Fencing will alleviate cattle grazing problems.
- Planting conifer windbreaks on exposed edges of the sugar bush will shield the stand from wind damage and other weather extremes (e.g. drying winds).
- Use the Conservative Tapping Guidelines where appropriate or as indicated in this manual.

Safety Considerations

There are four important operational considerations you need to follow before you can begin to take remedial action in your sugar bush.

1. **Operate safely** – dead, dying, stressed and injured trees represent significant hazards. If you are not accustomed to working around them it is a good idea to hire a professional
2. **Read the Label** – if you are using pesticides in your sugar bush be sure to read and follow the label carefully. Take the Grower Pesticide Safety Course (GPSC) and pass the GPSC exam. Only use pesticides which are approved for use by appropriate regulatory agencies.
3. **Take a first aid course and have first aid supplies on hand** – basic knowledge of first aid may help save a life.
4. **Do not work alone** – have a partner with you and a way of communicating with emergency authorities.

These operators are wearing proper safety equipment and monitoring each other's activities.

Maple Dieback and Decline

Maple dieback or decline is a progressive loss of vigour often caused by a complex combination of major stress factors. These stress factors can include very dry weather, flooding, frost, insect defoliation, damage from ice or wind and infection caused by various disease organisms.

These Sugar Maple leaves are showing symptoms of stress due to drought.

Historically, most dieback or decline events in Sugar Maple stands in Ontario were initiated by environmental factors such as adverse weather conditions. A healthy, vigorously growing woodland can withstand the effects of most single major stress factor events. However, when stress factors are combined, and occur during the same growing season, tree condition quickly begins to worsen (see Fig 33, p 87). As the stress levels increase, the naturally occurring defense mechanisms within the trees begin to fail. Decay fungi, such as *Armillaria* root rot, can rapidly begin to invade and colonize the trees' root systems.

Symptoms of decline in Sugar Maple trees are:

- Leaves may colour and drop prematurely in the fall.
- Leaves are often small, sparse and off-colour.
- Progressive deterioration of the crown beginning with death of buds and dieback of twigs starting at the margin of the crown and progressing inward and downward
- Terminal and radial growth may slow even before external symptoms are apparent.

A healthy, vigorously growing woodland can withstand the effects of most single major stress factor events.

This stand has been defoliated by Gypsy Moth caterpillars

Strong winds have caused extensive windthrow in this woodland.

The crowns actually die back in an attempt to balance the requirements of the tree, to maintain the crown mass and the ability of the stem and root system to supply these requirements. Dieback is a naturally occurring process for a tree under severe stress. A small amount of crown dieback, < 15% is normal and may occur yearly. With continued decline, the trees eventually lose their ability to respond to improved conditions.

Defoliation of approximately 60% or greater generally triggers refoliation. This involves the conversion of starch reserves into the simple sugars that are required for the manufacture of new leaves and buds. A great deal of energy is used in the process. The simple sugars are excellent energy sources for Armillaria. Their abundance stimulates the rapid growth of the fungus between the bark and the wood, girdling roots and lower stems. The change in the energy balance not only seems to promote the invasion of roots and root collars by Armillaria, but may also reduce the quality and quantity of sugar available for making syrup.

Managing Maple Decline

Management practices which promote sugar bush health represent the best strategy for reducing the potential impact of maple decline. Healthy trees are able to withstand more stress and will recover more quickly then unhealthy ones. A sugar bush exhibiting symptoms of maple decline will have a greater chance of a good recovery if management activities are adapted accordingly. Although little can be done in the case of prolonged and severe dry weather, some form of action should be taken during periods of high stress. By reducing stress levels, it may be possible to minimize any long-term impacts on the health and productivity of a sugar bush. Actions geared at reducing stress levels within a sugar bush may include:

- Follow conservative tapping guidelines for stressed trees, or don't tap at all if the trees are under severe stress.
- If possible, alleviate factors that are causing stress to the trees through management activities – fertilization may improve nutrient poor soils, liming may improve acidic soils, sprays or biological control may decrease infestations of defoliators.
- Conduct silvicultural activities wisely to improve the stand and to minimize any damage to remaining crop trees.
- Roads should be well planned for minimum impact on the sugar bush.

Severe Defoliation

This stand was completely defoliated by Saddled-prominent caterpillars.

Defoliation can be caused by a wide number of insect pests (see p 102). It is important to recognize that some level of defoliation happens every year, even in the healthiest of woodlots – caterpillars and other defoliating insects are a natural part of the biodiversity of your sugar bush. In most years defoliation is quite minor and often goes unnoticed by the sugar bush owner. In some cases however, defoliation can be severe and a significant portion of the crown can be lost in a very short time period. It is important to monitor your sugar bush closely throughout the year. Many times, caterpillar populations start to build up a few years before they cause severe defoliation. Check your property carefully and talk with other producers in your area – they too may be noticing a problem.

Early Season Defoliation

The timing of defoliation can have as great an impact on the tree as the actual severity of the defoliation. Trees defoliated in the very early part of the growing season, **during early May and June**, will produce a second crop of leaves and still have sufficient time during the growing season to photosynthesize, replacing and producing adequate supplies of sugar and starch. Hence, early spring defoliation has very little effect on the overall health and vigour of the trees.

Mid Season Defoliation

Mid season defoliation has the greatest overall impact on the health and vigour of trees. Trees defoliated during **late June to early July** will refoliate, but there is insufficient time left in the growing season to completely replenish the starch reserves that were used to produce the second flush of leaves. Loss of vigour and top dieback may become evident the following spring. Trees are not usually killed by a single mid-season defoliation event, but they will have a lower sap yield the following spring.

Late Season Defoliation

Trees defoliated in the late summer, **from mid-July to August** are less likely to refoliate and usually are not damaged. They have had most of the growing season for photosynthesizing and by early August growth is slowing down for the year and the tree is in the process of converting sugar back into starch and translocating it back to the root system. Similar to early spring defoliation, there is little impact on the tree.

Repeated (Same Year) Defoliation

Occasionally trees may be defoliated twice during the growing season, first **by an early spring frost** and then by a **mid summer defoliator.** This can have devastating effects on the woodlands, especially if the defoliation levels are severe each time. The incidence of whole tree mortality can be extremely high under these circumstances. Trees have two sets of buds. The vegetative buds that are produced annually and a dormant set of buds that are flushed if the vegetative buds are destroyed. When both types of buds flush in a single growing season and their leaves are completely consumed, the tree has no means to replace its depleted starch reserves and in many cases will die.

In the case of severe defoliation caused by the feeding of a major forest pest, aerial spraying of the woodlot to reduce and destroy the infesting population levels has proven to be very effective and beneficial. The woodlot owner is strongly advised to consult with a forestry professional if considering aerial spraying and for help in choosing a reputable spray company.

Sugar Bush Fertility and Soil pH

Fertilization

Most forest soils in Ontario have adequate nutrient levels for tree growth, but in some stands management has taken its toll on soil fertility.

Soil nutrients are cyclical in nature, trees grow and eventually die, returning their nutrients back to the soil in the form of leaves, twigs, logs and roots.

Management interrupts the nutrient cycle by removing nutrients from the site. For a typical sugar bush in southern Ontario – which may have been managed for the last 200 years – cattle grazing and sawlog and pulp/fuelwood removal have resulted in the depletion of hundreds if not thousands of kilograms (pounds) of nutrients per hectare (per acre) from the site.

This nutrient removal does not necessarily mean that the soils in your sugar bush are nutrient deficient. Soil and/or foliar (tree leaf) testing must be done to determine what (if any) nutrients may be in short supply.

Soil test results are very difficult to interpret for sugar bushes as there are no established minimum standards for Sugar Maple. Foliar

Application of fertilizer should be seen as an option to help alleviate an identifiable problem.

testing offers more promise as there are established standards to compare test results to (Table 20). Comparing foliar test results to these known ranges will provide general guidelines as to which nutrients may need to be added. Contact a certified agricultural soil testing lab for guidelines. Obtain information on when, where and how to properly sample soil and leaves.

Table 20: Range of selected nutrients in healthy vigorous Sugar Maple

Nutrient	Range in healthy trees (dry weight)
Nitrogen	1.6–2.3%
Phosphorus	0.08–0.18%
Potassium	0.55–1.04%
Calcium	0.5–2.2%
Magnesium	0.11–0.4%

Application of fertilizer should be seen as an option to help alleviate an identifiable problem. Indiscriminate application of fertilizer is poor management, a waste of money and may do more harm than good. Identifiable problems include crown dieback and reduced health and vigour of Sugar Maple trees (see Table 21).

An example of efficient use of fertilizer might be as follows. Trees in one area of the sugar bush are not as vigorous as they were 5–10 years ago. Some leaf discoloration is visible, and there is minor crown dieback at the tip of many branches. Foliar samples sent to the lab come back as: 2% Nitrogen, 0.15% Phosphorus, 0.3% Potassium, 0.6% Calcium and 0.2% Magnesium. Potassium is the only nutrient outside the range of healthy trees, so applying a small amount of Potassium fertilizer to this area of the bush is a good risk investment.

The application of a fertilizer and lime to your sugar bush can help correct nutrient and pH imbalances in the soil.

Fertilizer additions should be made in small amounts, aiming to make small changes over time. The ice storm research study (Appendix E) applied 200 kg/ha of both phosphorus and potassium in the spring and showed promising results with no visible negative impacts on the trees.

Table 21, on the following page, lists potential symptoms caused by the deficiency of five nutrients. If you see similar symptoms in your sugar bush, you should investigate the possibility of a potential fertility problem. It is also important to recognize that many of these symptoms may be a result of more than one causal factor including drought. Attributing foliar symptoms to a soil nutrient imbalance requires thorough investigation which includes ruling out other potential causes.

Note that regulations for organic certification currently do not permit the use of synthetic fertilizer in the sugar bush and may restrict the use of organic fertilizers as well.

Table 21: **Nutrient deficiency symptoms**

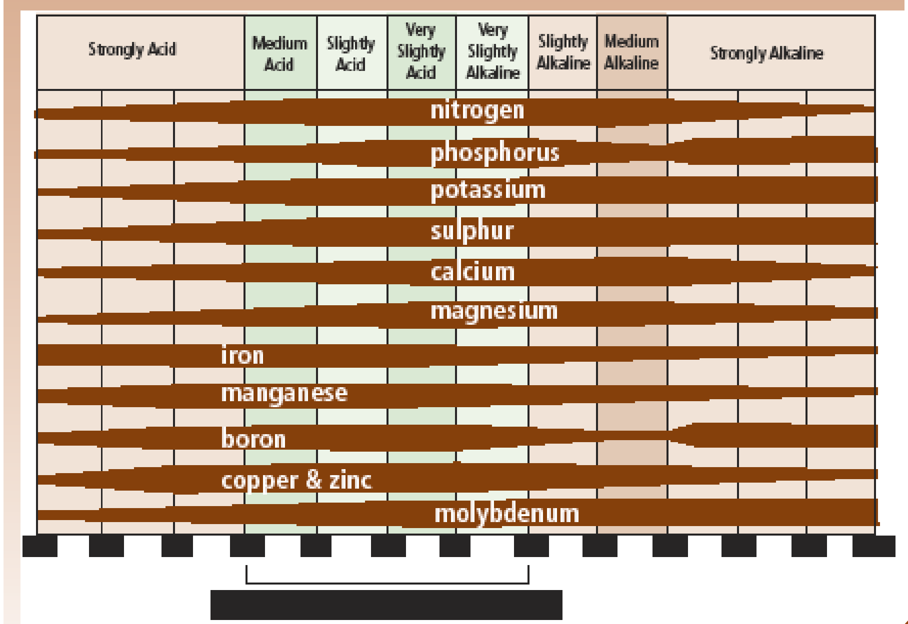
Nutrient	Important for:	Foliar Deficiency Symptom
Nitrogen	Proteins, nucleic acids, chlorophyll, vegetative growth	• Yellowing of the leaves (termed chlorosis) • Slow, stunted growth
Potassium	Photosynthesis and respiration, starch and protein synthesis, water regulation	• Mottling, chlorosis, or death of leaf edges
Phosphorus	Photosynthesis, DNA and RNA, energy metabolism, root establishment and growth	• Leaves dark green or dark greenish-purple • Leaves often smaller and may be malformed or have spots of dead tissue
Calcium	Cell division, formation of cell walls, membrane functioning	• Yellowing of leaves similar to nitrogen deficiency • Young leaves often deformed, with dead tissue • Symptoms appear first in growing tissues
Magnesium	Chlorophyll (photosynthesis), ribosomes, activation of enzymes	• Bright yellowing or oranging of all or part of the leaves, particularly between the veins of the leaves

Liming to Improve Soil pH

Sugar Maple can grow on soils ranging from strongly acidic (pH 3.7) to slightly alkaline (pH 8.0), but is most commonly found on soils with a pH of 5.5 to 7.5. Susceptibility to stress and certain nutrient deficiencies are more prevalent with Sugar Maple on more acidic soils. The majority of nutrients are most readily available at a pH of approximately 6 to 7 (Figure 34). Because of this, calcareous soils which were derived from basic bedrock types (e.g. limestone) are beneficial in a sugar bush. They buffer acidic inputs from sources such as acid rain, reducing the likelihood of pH changes that would result in soil acidification. If your soil is acidic, lime may be applied to increase pH.

Figure 34: **Soil Nutrient Availability Diagram**

The availability of nutrients is in part related to the pH of the soil. In this diagram, the wider the bar, the more available a nutrient is to the tree.



Source: Ontario Maple Orchard Directory,
Ontario Ministry of Agriculture, Food and Rural Affairs

Fertilization, with nitrogen in particular, may stimulate vigorous undergrowth, which may compete with Sugar Maple for water and nutrients. This could result in gradual change in species composition of the site.

Benefits of Fertilization and Liming

Benefits that may be realized from fertilization and/or liming are as follows:

- Nutrients that are deficient in the soils may be replenished by fertilization increasing what is available for uptake by the trees.
- Growth and vigour of the Sugar Maple trees may increase. This may result in healthier, more productive trees with greater sap flow and sweeter sap.
- Nutrients which are present but are unavailable to the tree because of a soil pH imbalance may be made available by the application of lime.

Management Considerations for Fertilizer and Lime Applications

Professional help and advice should be obtained before any decisions are made to fertilize or lime your sugar bush because their application is not without its risks. Some factors to consider are:

- The cost of the application may outweigh potential benefits.
- Regular applications may be necessary in some soils.
- The interactions within a forest are complex; fertilization and liming may produce unexpected results and adversely affect the health of Sugar Maple trees or another aspect of the forest ecosystem.
- Depending on the site, a greater response may be observed through other management activities such as thinning the sugar bush or tapping more conservatively.
- Fertilization, with nitrogen in particular, may stimulate vigorous undergrowth, which may compete with Sugar Maple for water and nutrients. This could result in gradual change in species composition of the site.
- Machinery used for fertilizer application could potentially damage roots or stems of crop trees.
- Over fertilization or application of nutrients that are not lacking on the site may further aggravate nutrient imbalances, resulting in a decline in tree health.
- Trees lacking vigour may not be able to respond to fertilizer applications, even on poor soils.
- Leaching of fertilizers may cause eutrophication (greatly increased nutrient levels and decreased oxygen levels) of water sources following periods of heavy rain.
- Application of nitrogen should not be made after the middle of summer. This avoids potential problems caused by stimulating vegetative growth too late in the season.
- Application of nitrogen in the spring to already stressed trees may cause a further depletion of carbohydrate reserves.
- Ensure that the application is done evenly throughout the sugar bush.
- In some cases, liming could induce nutrient deficiencies, particularly phosphorus and potassium.
- Applications of liquid lime have been found to be more effective than granular lime although granular lime has been known to produce satisfactory results and is easier to apply.
- Dolomitic lime (lime + magnesium) is commonly used, particularly where magnesium deficiencies exist.
- Straight lime may be used in situations where magnesium is not required.
- It may take a year or more before the effects of liming are apparent.

Drainage

Sugar Maple prefers fresh soils with adequate drainage. Although it can grow on dry or moist sites, it does not thrive and will often die well before it reaches maturity. Sugar Maple rarely survives in swamps. Sugar bushes are especially vulnerable to increases in the water table caused by road building, beaver activity or seasonal flooding.

Road building, especially with gravel may cause alterations to the natural drainage of the soil. If a new road increases the height of the water table during the growing season, tree roots may not be able to absorb water, oxygen and nutrients adequately resulting in tree decline. Seasonal flooding may cause problems for upland hardwood stands where the predominant species are Sugar Maple and / or Black Maple. Sugar Maple is extremely sensitive to seasonal flooding and is often replaced on wet sites by more water tolerant species, such as Red Maple, Silver Maple, ash and poplars.

Brian Lockhart, USDA Forest Service, www.forestryimages.org

Sugar Maple cannot tolerate seasonal flooding. Mature trees will decline and regeneration is lost or inhibited. Flooding may result in decline or dieback of Sugar Maple stands.

Management Options for Poorly Drained Sites

1) Improving Drainage

Wet areas can sometimes be economically drained, dramatically improving the quality of the site for Sugar Maple establishment and growth. Depending on the extent of the drainage project, a backhoe or high hoe may be used. Well planned and laid out drainage ditches, that are annually inspected and maintained, can turn unproductive areas of the sugar bush into areas that produce high quality, productive Sugar Maple trees. In some cases, side trenches need to be established depending upon the size of the wet area and the degree of slope on the surrounding terrain.

It is advised however, that you thoroughly investigate potential negative implications of improving drainage on your property. In many cases, the assistance and recommendations of a professional drainage firm is strongly advised. Keep in mind the following:

- By draining a wet area, the entire water table in the vicinity may be altered or lowered and can have a direct effect on the entire woodland and adjoining areas.
- There may be rules and regulations pertaining to the altering of drainage patterns – check with your local Conservation Authority and the Ministry of Natural Resources before you dig.
- You are liable for your actions – affecting your neighbours property could be costly.

2) Controlling beaver floods

Beavers are a natural part of the forest ecosystem but they can sometimes conflict with sugar bush operations. Beaver floods and dams can raise the water table and have a serious impact on the health of a sugar bush. Minimizing beaver associated problems can be accomplished in a number of ways, including:

Thoroughly investigate potential negative implications of improving drainage on your property.

Paul Bolstad, University of Minnesota, www.forestryimages.org

- **Trapping** – licensed trappers are available and can reduce the beaver population significantly. Contact the Ministry of Natural Resources for a list of trappers in your area.
- **Beaver Bafflers** – a beaver baffler is a device installed in a dam to control water levels. As the name suggests, beavers are unable to stop the water from draining. In many cases, the beavers will move on to other areas or the flooding is controlled reducing the impact on the sugar bush.
- **Monitoring** – Look for signs of beaver activity. You may be able to prevent problems from happening by destroying early signs of a beaver problem. Exercise caution however if you are thinking of removing an established dam. Your actions may cause more severe problems down stream.

3) Road construction

Design your sugar bush roads well and try to minimize the number of constructed roads you may have. Seasonal flooding is often the result of some previous management operation that has been conducted in the woodlot, such as road construction. Areas that would have naturally drained during periods of high seasonal water levels often become trapped behind poorly designed and laid out road systems. The roads become dams, holding back spring run off and create what is commonly referred to as seasonal perched water table.

The primary problem is usually the absence of, or the poor placement of, culverts. Many culverts are set too high or have no accompanying discharge ditch on the downward side of the slope. A discharge ditch should extend out from the culvert approximately 200 metres (656 feet) on the downstream side of the road, or a sufficient distance to cross at least a half to three quarters of a meter drop in elevation thus avoiding any backup at the culvert. Another common problem is the use of small-diameter culverts that are not capable of handling the volume of water that collects and thus are not capable of adequately draining the area.

Billy Humphries, Forest Resource Consultants, Inc., www.forestryimages.org

In many cases, a well placed culvert can alleviate many seasonal flooding problems.

Invasive Species

Invasive species are plant, insect, disease and animal species that are found outside their normal range. They pose a direct threat to the economic, ecological or social functioning of the area in which they have become established. Invasive species are a global problem. In recent years, the number of species being transported to new environments has increased.

Although their impacts are currently limited, invasive species do represent a threat to the functioning of Ontario's sugar bushes. For this reason, it is important to stay informed on the issues associated with invasive species in the province, and to monitor your sugar bush regularly for health related problems. Early identification is vital to minimizing the potential impacts.

Some established species are affecting sugar bushes in certain parts of the province. Most of these species pose a significant risk to sugar bush health and productivity. New species are imported into Canada each year. The following are some of the more significant invasive species.

Buckthorn (Glossy and Common)

Common Buckthorn (also known as European Buckthorn) is now impacting some sugar bushes in Ontario.

The two species of Buckthorn in Ontario favour slightly different habitats. *Common Buckthorn* prefers more upland areas and represents the greater threat to sugar bush operations. It is difficult to eradicate and will often interfere with maple regeneration. It does not pose a problem to established trees.

Control: Buckthorn like all invasive plants is much easier to control when it is detected early. Learn what to look for, and if you find it, take immediate steps to eradicate it. Some control has been successful through the use of herbicides and mechanical removal.

Management Options: Control in an infested woodlot is seldom successful. If you have a significant problem, it is advisable to keep the buckthorn around the maple regeneration at bay until the seedlings have become well established and have grown to at least 3 m (10 ft) in height. Promoting future maple trees will be a significant amount of work in infested sugar bushes.

Garlic Mustard

Garlic Mustard is a biennial plant that in the right environment can crowd out other plants and regenerating trees. It was, like most invasive plants, first introduced as a garden plant. It does not do as well on soils with a high pH.

Control: Herbicides do work but when the infestation is substantial they may be impractical. Mechanical removal can also work on small areas.

Management Options: Identify and promote individual maple seedlings. This can be done through the strategic use of herbicides or cutting or pulling of the competing garlic mustard. Keep the plants at bay until the maple seedlings have reached approximately 1 m (3 ft) tall. Be wary of using lime to raise soil pH if you have garlic mustard in your sugar bush (see p 91).

Garlic Mustard is an aggressive plant which can completely occupy large areas of the forest floor.

Gypsy Moth Caterpillar

A mature Gypsy Moth caterpillar.

Gypsy Moth is native to Europe and southern Asia and was first introduced into North America in the Boston area in about 1869. The first Ontario record occurred in 1969. It has been estimated that more than $100 million has been spent, primarily in the United States, in an attempt to stop or slow the spread of this insect across the hardwood forests of North America.

For more information on the Gypsy Moth see page 102.

It is very important that fuelwood and other tree parts not be transported from areas under quarantine for Asian Long-horned Beetle and Emerald Ash Borer.

Emerald Ash Borer

The Emerald Ash Borer (inset) is not known to attack maple trees but it can disrupt the overall diversity of the woodlot. In the background image, bark has been peeled off to show underlying damage caused by this beetle.

The Emerald Ash Borer is an aggressive invasive beetle which feeds on ash trees. It can kill a tree in as little as one or two years. If your sugar bush has a high component of ash you may see increased ash mortality in infested areas only. This can have an impact on stand structure and composition.

The Emerald Ash Borer is currently found in southwestern Ontario, in the municipalities of Essex and Chatham-Kent. The Canadian Food Inspection Agency prohibits the movement of ash materials (including nursery stock, trees, logs, lumber and wood with bark attached, woodchips, bark chips and debris) or firewood of any species out of either of these Regulated Areas. For additional information on the Emerald Ash Borer please visit: *www.inspection.gc.ca* .

Control Options: none presently

Management Options: If your sugar bush is in an infested area, you will probably lose any ash trees you have in the woodlot. Take this into consideration if you are planning to harvest trees. Even a healthy ash will probably not survive until the next cutting cycle.

Asian Longhorned Beetle

The Asian Long-horned Beetle adult and larva.

Of all the invasive species in Ontario, the Asian Long-horned Beetle poses the most threat to the maple industry. It has been found at various locations in the United States since 1996 and in 2003 it was first detected in Canada in the Woodbridge area of southern Ontario. Currently, there have been no sightings outside this area.

For current status reports visit the CFIA web site: *www.inspection.gc.ca*

In Ontario, the Asian Long-horned Beetle has a one to two year life cycle. Adult beetles generally emerge in July and August and live as late as the first frost. The adults show a preference to the tree species from which they had emerged and often remain on the tree or fly a short distance to another suitable host. The adults feed on new foliage, the bark of young new shoots and on leaf petioles. After mating the females chew oval grooves, ovipositing sites, in the bark of the tree into which she deposits a single egg. The female will live for approximately 30 to 40 days, laying some 25–40 eggs. The eggs are usually laid on the east side of the main trunk or on branches greater than 5 cm (2 in) in diameter. The eggs hatch in about two weeks and the young larvae begin to feed in the cambium layer just under the bark. As the larvae mature they migrate into the wood of the stem or branch, creating large tunnels as they feed. Mature larvae pupate in chambers at the end of the feeding tunnel. The young adults emerge from the tree through large round exit holes about 10–15 mm (3/8 to 9/16 in) in diameter. The Asian Long-horned beetle may overwinter as an egg, larvae or pupa.

Control Options: none presently – the key to preventing a major problem is early detection. The full co-operation of the general public is required if eradication programs are to be successful. If you suspect the presence of the Asian Long-horned Beetle, please contact your nearest Canadian Food Inspection Agency (CFIA) office, or Natural Resources Canada – Canadian Forest Service (NRCAN - CFS) office.

Management Options: none – do not change your management approach. This pest has not as of yet impacted a sugar bush in Ontario. It is strongly recommended that you learn to identify the insect and the signs of infestation.

Of all the invasive species in Ontario, the Asian Long-horned Beetle poses the most threat to the maple industry.

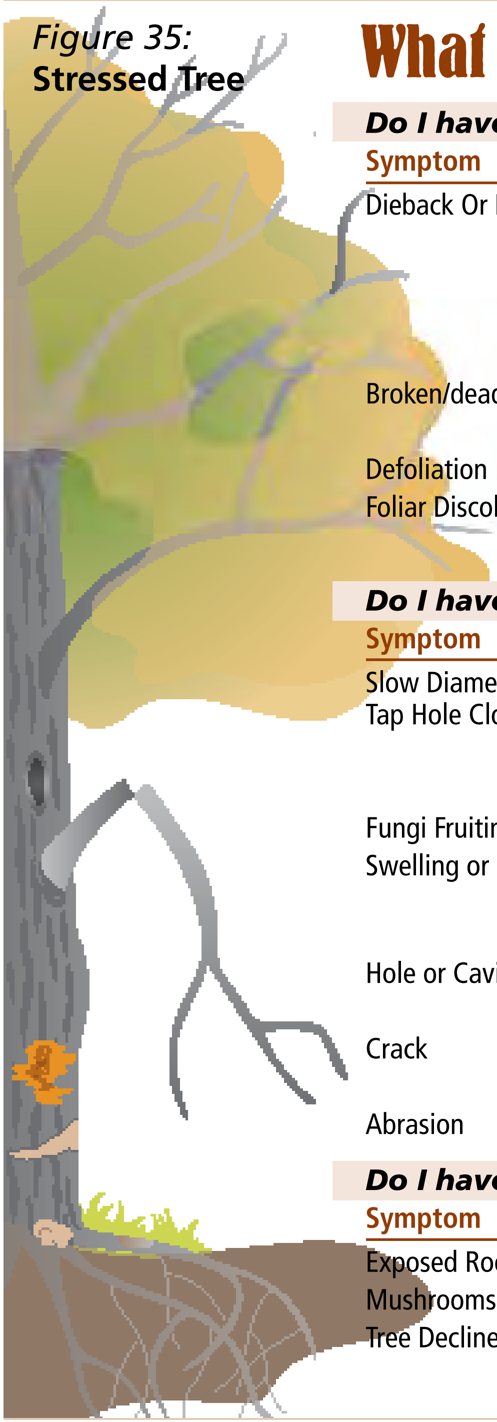


Figure 35: **Stressed Tree**

What is Wrong with My Tree?

Do I have a Crown Problem?

Symptom	Cause	Reference In Manual
Dieback Or Decline	Drought	p 113
	Root Damage	pp 32, 95, 112
	Defoliation	p 90
	Overstocking	pp 46, 48, App. D
	Flooding	p 95
Broken/dead Branches	Storm Damage	p 115
	Animal Problems	p 112
Defoliation	Insects	p 100
Foliar Discoloration	Infertility	p 91
	Poor Drainage	p 95

Do I have a Stem Problem?

Symptom	Cause	Reference In Manual
Slow Diameter Growth/ Tap Hole Closure	Unproductive Site	p 20
	Overstocking	pp 46, 48, App. D
	Tree Decline	p 89
Fungi Fruiting Bodies	Disease	pp 107, 110
Swelling or Growth Deformity	Disease	p 107
	Wire Or Spile Embedded In Tree	p 78
Hole or Cavity	Decay	pp 107, 110, 116
	Bird/animal	p 112
Crack	Insect	p 104
	Frost	p 114
Abrasion	Harvesting Damage	p 116

Do I have a Root Problem?

Symptom	Cause	Reference In Manual
Exposed Roots	Grazing	p 112
Mushrooms	Disease	p 108
Tree Decline	Flooding	p 95
	Very Dry Weather	p 113

The sugar bush owner should have a thorough understanding and knowledge of the various life cycles of the major forest pests.

Forest Pests

There are hundreds of insects and diseases that attack forest trees in Ontario. Fortunately only a few are classified as major forest pests, capable of killing or severely damaging trees over large areas. Most pests are classified as minor forest pests, capable of sporadic or localized injury to trees, but do not usually pose a threat to healthy trees. Their feeding activities will frequently cause unsightly damage to maple trees, but have little effect on overall health and vigour.

Not all insects or diseases are harmful to forest trees and not all harmful forest pest populations need to be controlled. If damage levels are light, most go unnoticed and have little impact on the trees. There are numerous insects and diseases that are beneficial to the woodlands, helping cross-pollinate trees and recycling organic matter and nutrients back into the forest soils. Others are naturally occurring parasites that help to control major forest pests. Their population levels should be encouraged whenever possible. However, epidemic levels of major forest pests can have an impact on tree vigour and growth, alter tree form and cause branch and whole tree mortality. Disease-causing fungi are present in all sugar bushes and are believed to be responsible for the loss of more productivity than all the other factors combined. Healthy, vigorously growing trees are more resistant to most pest problems and are better able to overcome periods of severe defoliation or infection than trees that are unhealthy or in a stressed condition.

Knowledge of Forest Pests

The sugar bush owner should have a thorough understanding and knowledge of the various life cycles of the major forest pests. Being able to identify the most common major pests would definitely be an asset. It is important to become familiar with the various signs and symptoms of the more common major pests. **Signs** include the actual defoliation by an insect or the conks or mushrooms produced by a disease organism. **Symptoms** are changes in the tree that occur as a result of injury, and would include conditions such as wilted leaves, foliar discoloration, premature leaf drop, branch or stem swellings or galls, bleeding and cankers.

Not all damage is the result of forest insects and diseases. Damage may also be caused by feeding or nesting activities of birds and animals or the grazing of cattle. Having a working knowledge of what, where and when to look for the damage caused by forest pests will be very helpful in the identification and management of the pest. Before any control is attempted, especially if the use of a pesticide is contemplated, the sugar bush owner is strongly urged to consult with a forestry professional.

More information on forest pests affecting maple operations can be found at: www.glfc.forestry.ca/sugarbush/

Controlling Forest Pests

Maple syrup is considered an agricultural product and as a result, producers must follow the same rules other farmers do when applying pesticides. To purchase and apply the more hazardous pesticides (Schedules 1, 2 or 5), a syrup producer must first be classified as a Certified Agriculturist. Every farm business that uses Schedule 1, 2 or 5 pesticides must have at least one person classified as a Certified Grower. To become a Certified Grower, a producer must attend a one-day Grower Pesticide Safety Course and pass an exam. Producers may choose to hire a licensed pesticide applicator if they do not want to do the applications themselves.

There are options for sugar bush owners with insect problems.

Options for Insect Control

Producers who wish to use pesticides in their operations need to do so cautiously. Use pesticides only when it has been determined that an infestation of a major forest pest will have a significant impact on the sugar bush. Controlling an infestation during the early stages of an infestation may be easier to achieve than during the peak of the outbreak. Carefully read the product label, confirm that the product is registered for use against the target pest and follow the label instructions for handling, mixing, application rates and safety precautions.

Note: the use of chemical pesticides may not be permitted if the maple operation is certified organic.

Forest Tent Caterpillars

Caterpillars and other defoliators can often be controlled through the aerial application of an insecticide. The biological insecticide, Bacillus thuringiensis, (B.t.) is considered to be the product of choice for controlling some species of caterpillars like Gypsy Moth and Forest Tent Caterpillar. Application timing is essential however for effective control.

USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org

Numbers of some forests pests can be reduced by trapping the larvae on a band of sticky material, such as Tanglefoot®, spread on the trunk of the tree. This option is only practical on a small scale. Warning: only use products specifically designed to trap caterpillars – grease and other petroleum based substances may injure or kill a tree.

Major Insects

Forest Tent Caterpillar

Egg band

Pupa

Adult

Egg Winter is spent as tiny larvae inside the egg, which are laid in bands, consisting of a hundred or more eggs, that completely encircle last year's twig.

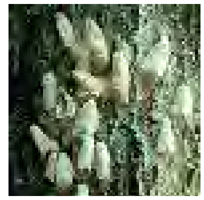
Larvae Emerge the following spring in late April to mid May, about the time the poplar buds begin to open. They feed on the expanding foliage for approximately six weeks, congregating on the main stem or larger branches during the day to rest and molt. When a tree is completely stripped of foliage, the larvae will migrate to other trees or shrubs in search of food. Full-grown larvae are about 50 mm (2 in) long, hairy, bluish-black with typical white keyhole marks along the back.

Pupae Pupate in mid- to late- June in silken cocoons in rolled leaf clusters.

Adult Buff brown adult moths emerge in about two weeks, mate, lay their eggs and die. The adults do not feed.

- One of the most common and destructive forest pests affecting sugar bushes
- Causes widespread and severe defoliation at 10 to 12 year intervals
- Infestations generally persist for three to five years
- Preferred hosts include poplar, Sugar Maple, oak, ash and birch

Gypsy Moth



Female & eggs

Pupa

Larva

Egg Egg masses are flat and oval in shape, buff-brown in color and contain from 100 to 1000 eggs. They are laid in numerous semi-sheltered locations, such as in crevices on the trunks or branches of trees, in cavities, or under debris on the forest floor.

Larvae The young larvae crawl up the tree soon after hatching in late April to late May and begin feeding on the expanding foliage. When disturbed they drop down on silken threads and are often dispersed over long distances by the wind. Young larvae chew small, round holes in leaves. Older larvae feed from the leaf edges, consuming the entire leaves except for the larger veins and the middle rib. They feed mainly during the night and rest during the day, congregating in large masses on the underside of the major limbs or on the lower main stem. If all of the foliage is consumed, they will migrate to other trees and shrubs in search of food. Fully grown larvae are 40 to 65 mm (1 1/2 to 2 in) in length, with a yellowish head with black markings. The body is very hairy and dusky in color with a double row of five pairs of blue spots followed by a double row of six pairs of red spots along the back. Feeding can last for up to six weeks.

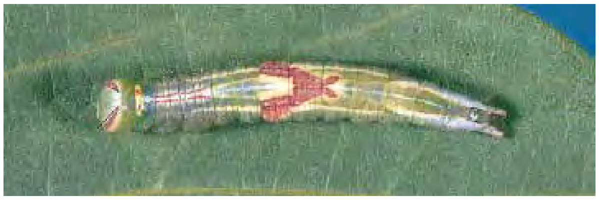
Pupae Takes place in sheltered places either on the tree or under debris on the forest floor.

Adult Present from mid-July until early September. The female rarely, if ever, flies and usually crawls a very short distance from her pupation site.

- Larvae will feed on most deciduous and conifer trees but prefer oak, poplar, and birch.
- During periods of high populations, sugar bushes are frequently defoliated.

- Repeated outbreaks tend to occur in stands dominated with the more preferred host species, primarily oak.
- Caterpillar can cause temporary allergic reactions in some people.
- Populations of saddle prominent should be controlled in sugar bushes that are under stress from severe dry weather or have recently been thinned

Saddle Prominent



Larva

Egg Pale green, laid singly on the lower surface of the leaves throughout the crown

Larvae Initially skeletonize the lower surface of the leaf. They begin to feed on the leaf edge as they mature and eventually consume the entire leaf except for the main veins. They often migrate from tree to tree and may collect in large numbers at the bases of heavily defoliated trees. When fully grown, by mid- to late August, the larvae are about 40 mm (1 1/2 in) in length, elongated and bulging toward the center of the body. The color varies from pale green to reddish brown and the back is marked with lines of various colors and patterns. The most common pattern is a saddle-shaped, brownish red spot in the middle of the body.

Pupae Mature larvae drop to the ground, pupate in the humus layer and overwinter.

Adult Emerge in mid-June, mate, lay eggs and die

- 1967 to 1971, approximately 2.5 million km^2 (965,000 million square miles) were devastated by the saddle prominent in southern Ontario.
- The preferred hosts include beech, maple and birch but it will feed on a wide range of hardwoods.
- Healthy, vigorously growing canopy trees can survive two years of severe defoliation (>75%), but crown damage is usually very extensive.
- Tree mortality can be very high in the understory sapling and pole-size trees.
- During years of heavy defoliation, it is strongly recommended that tapping be very conservative the following spring.

Bruce Spanworm

Female

Male

Larva

Egg Laid singly in bark crevices, under loose flakes or in lichens in fall

Larvae Emerge in spring as the buds begin to break and feed from the underside of the leaves, consuming all of the green leaf material except for the main ribs or veins. They often feed from inside a shelter created by folding over a leaf and tying it together with silk. If the majority of the leaves have been consumed, the larvae will drop down on a silken thread searching out additional food lower in the crown. When this occurs, they are frequently carried off by the wind to new areas, often over great distances. The larvae reach maturity in about five to seven weeks, usually by late June. All young larvae are pale yellowish-green, with three white stripes running the length of the body. As the larvae mature, some of the populations remain yellowish-green, others turn dark brown in color, but both retain the white stripes

Pupae Drop to the ground and form cocoons in the duff layer, pupating in the fall and emerging as adults

Adult Appear in October and November, well after the first frosts of the year. The adults become active at sunset. The wingless female crawls up to the lower portion of the trunk.

- Periodically causes severe defoliation in hardwood stands throughout Ontario
- Preferred hosts include maple, beech and aspen .
- Infestations typically last two to three years and then completely collapse.

- Large tracts of mixed hardwood forest can be completely defoliated
- Infestations are usually very short lived controlled naturally by inclement weather, starvation, natural predators, parasites and especially diseases
- Human intervention is rarely required and to date no whole tree mortality has ever been reported
- Severe defoliation in sugar bushes has not been proven to adversely affect the quality or quantity of sap flow

Fall Cankerworm

Eggs

Larva

Egg Laid in single-layered egg masses of 100 or more on the bark of small branches or twigs high in the crown

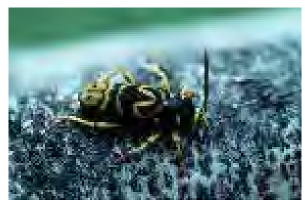
Larvae Emerge the following spring as the buds begin to open, usually in late April or early May. The young larvae begin feeding on the opening buds and expanding foliage, skeletonizing the new leaves. Young, tiny larvae are easily disturbed and often drop down on a silken thread. The thread breaks, and the young larvae are carried off by the wind, and can be transported a considerable distance. As the larvae mature over the next five or six weeks, they consume the whole leaf except for the main ribs. When all of the foliage in the upper crown is consumed, the larvae will drop down on silken threads to lower branches. Full-grown larvae are 25 mm (1 in) in length, are light green to dark blackish-green in color. The light-colored forms have several distinct longitudinal whitish lines, and the darker forms have a black stripe along the back.

Pupae By mid- to late June, larvae are mature and drop to the ground and pupate in the soil

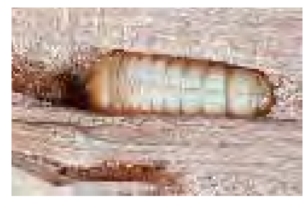
Adult Emerge with the onset of cold weather in October and November after the first heavy frosts. The wingless, greyish-brown female crawls up the tree and deposits her eggs.

- Infestations appear very suddenly, are short lived (3–4 years) and quickly collapse.
- Infestations begin as small, widely scattered pockets that soon coalesce and cover large areas.
- Prefer Elm, Basswood, maples, Red Oak and apple
- Larvae are often referred to as loopers or inchworms.
- Two or more years of severe defoliation (>75%) may result in branch and whole tree mortality.
- Tanglefoot ®, spread on the trunk of the tree in the fall when the adults are emerging. The females are wingless and have to crawl up the tree to lay their eggs.

Sugar Maple Borer



Adult



Larva

Egg Deposited in July and August eggs in bark crevices or in holes chewed in the bark, usually on the lower six metres (20 feet) of the main stem

Larvae Upon hatching the young larvae bore through the bark and begin feeding on the surface of the sapwood. They construct tunnels that run more or less across the grain and cut deep into the wood. At the end of the first summer they construct a chamber in the sapwood and overwinter. The following spring feeding resumes, with the larva cutting an even larger groove across the sapwood as they mature and increase in size. Sometime during the end of the first or beginning of the second year the direction of the gallery changes from across the grain to almost vertical. Typically, a heavily scoured "J" shaped feeding scar is formed in the sapwood.

Pupae At the end of the second summer the mature larva bores deep into the wood and constructs a pupal chamber at the end of the tunnel and overwinters. Before entering the chamber, it cuts an exit hole through which the adult will emerge. Pupation occurs late the following spring and adults emerge in mid June.

Adult Is a large blue black beetle with four narrow yellow bands across the back, one of which forms a W-shape. The tips of the hard wing coverings are yellow with a black dot.

- One of the most destructive pests of Sugar Maple in Ontario.
- Damage is always greater in open grown stands with a high component of Sugar Maple.
- Incidence levels ranging from 5 to 50% have been recorded in Sugar Maple woodlots in Ontario.
- Attacks Sugar, Red and Silver Maples
- Two year life-cycle covering part of three consecutive years.
- Tree are rarely killed by a single attack.
- Repeated attacks can kill the tree.
- Damage results in the partial girdling of the main stem of the tree and possibly the death of a portion of the crown.
- Girdling action reduces the available space for tapping.
- No mechanical or chemical controls
- Sound management practices to maintain healthy trees reduce the incidence and level of attacks
- Infested trees should be removed during any thinning operation and burnt before the adults emerge.
- Over-cutting should be avoided, as incidence levels greatly increase in poorly stocked stands.

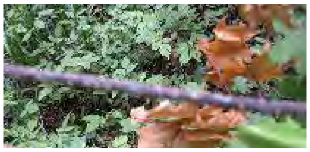
There are two species of insect currently not found in Ontario which are causing significant damage to sugar bushes in other jurisdictions. Pear Thrips and Lecanium Scale could become major insect pests in local sugar bushes if their range expands to Ontario.

Pear Thrips

Adult

- Tiny introduced insect which cause abnormal deformation of maple leaves.
- Crown takes on a thin appearance as leaves become distorted and discouloured (mottled yellow to green brown).

Lecanium Scale:



- Tiny insect which feeds on sap in leaves and twigs
- Feeding causes excretion of sticky sap referred to as 'honeydew'.
- Severe infestations can cause premature leaf drop and reduce tree vigour.

Minor Insects

Greenstriped Mapleworm

Larva

- Occasionally occurs in high numbers in small, localized areas
- Tree mortality has been recorded following three years of severe defoliation (>75%).
- Sap quality of Sugar Maple is usually lowered following years of heavy defoliation.
- Larvae consume the entire leaves except for the main veins.

Orangehumped Mapleworm

Larva

- An occasional pest of Sugar Maple, American Beech, and Basswood
- Little impact from this late season defoliator, unless infestations persist for three or more years
- Larvae can be hand-picked and destroyed or sprayed with a bacterial type of insecticide.

Linden Looper

Larva

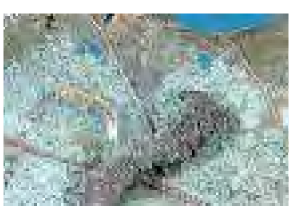
- Commonly causes of short-lived defoliation events in Sugar Maple stands
- Basswood is the preferred host.
- Larvae are wasteful feeders, only partially eating a leaf then moving on to another.
- Colour intensity can vary.
- Adult female is wingless.
- Tanglefoot® spread on the trunk of the tree in the fall is an effective mechanical control .

Maple Leaf Cutter

Damage

- Sugar Maple is the preferred host and repeated severe defoliation can affect sap quality.
- Larvae feed from within a protective case that is constructed from two discs cut from the leaf tissue, creating round, circular holes.
- The case is portable and moved to new feeding sites on the leaf surface where it is anchored by silken threads.
- New, larger discs are cut and stacked into the case as the larvae mature .
- Leaves turn brown and are covered with circular, partially skeletonized areas and several circular holes.

Maple Trumpet Skeletonizer



Larva & damage

- Often found in high numbers in very localized areas.
- Damage is usually not very serious.
- Sugar Maple is the preferred host.
- Larvae construct an elongated, often curved, tube of excrement and silk into which it can retreat.
- Leaf has a skeletonized, crumpled or pleated look.
- Control measures are rarely necessary.

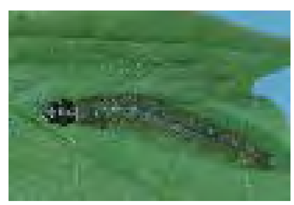
Maple Webworm

Larva

Damage

- Infestations usually develop in the crowns of open grown or poorly stocked maple stands.
- Large numbers can also build along the outer edges of well-stocked stands.
- Prefer a wide variety of hardwoods, including maples, oak, elm, beech, and aspen
- Mature larvae are about 25 mm (1 in) long, mottled and striped, and vary in color from pale yellow to greenish brown or black.
- Older larvae web together groups of leaves as they feed.
- Chemical insecticide controls are not usually necessary.

Maple Leafroller



Larva

- Occasionally causes epidemics in very localized areas in Ontario
- Larvae feed on all varieties of maples.
- Mature larvae vary from pale yellow to shades of green to dark brown.
- Young larvae initially feed inside the swollen buds and later, in May and June, feed on the new foliage from within loosely rolled or folded leaves.
- If control is required, spraying the foliage with a bacterial or stomach insecticide in mid May should be very effective.

Maple Petiole Borer

Larva

Damage

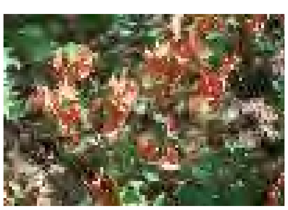
- Often found in high numbers in localized areas in Ontario
- Impact on the overall vigour is not significant
- Sugar Maple is the preferred host.
- Young larvae tunnel into the petiole and the leaf soon breaks off near the leaf blade.
- The ground under the infested trees is strewn with cut off, green leaves.
- Control measures are rarely necessary.
- Where only a few trees are encountered, the leafless petioles can be picked and destroyed.

Maple Spindlegall Mite

Mites

- 3 Common gall mites found on maples
- Maple spindlegall mite is found on Sugar Maple.
- Adults and larvae are microscopic.
- Feeding initiates abnormal cell development which develop into galls.
- Mites are very prolific and cause large numbers of galls to form over the course of the summer.
- Control methods are usually unwarranted.

Pitted Ambrosia Beetle



Damage

- Primarily a pest of regeneration
- Actively feeds on many hardwoods, but young Sugar Maples are especially subject to attack
- Adults bore deep into the wood of the main stem of the seedling, at ground level, and form spiral tunnels that girdle the stem.
- Damage is generally very localized and may appear to be having significant impact on the Sugar Maple regeneration
- May provide a benefit in some circumstances by thinning densely stocked regeneration areas

Major Diseases

Eutypella Canker

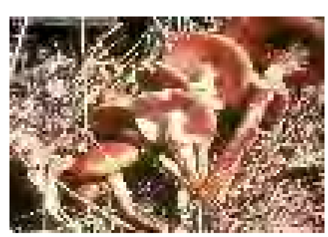
- A perennial stem canker that infects Sugar and Red Maples, and occasionally Manitoba, Norway, and Silver Maple
- Incidence rates in maple stands average 1 to 4%, but infection rates of 10 to 20% are common.
- Spores that are capable infecting other host trees during moist periods throughout the growing season.
- Spores rarely travel more than 100 m (328 ft).
- The majority of cankers (90%) occur at less than 4 m (13 ft) from the ground on the main stem of the tree and can reach a length of 1.5 m (5 ft).
- Trees of all ages are prone to attack.
- Trees under 12 cm (4 1/2 in) in diameter are usually girdled and killed.
- Trees more than 12 cm (4 1/2 in) in diameter are seldom killed and may live for many years with the canker enlarging in size as the tree grows.
- The canker eventually becomes an entry point for other stem diseases.
- The tree becomes quite susceptible to wind breakage.
- The removal and disposal of old cankered trees is strongly recommended and should help to reduce the spread of this canker disease to adjacent healthy trees, especially in stands where young regeneration is prevalent.
- Avoid damaging the main stems of trees during thinning operations.

Nectria Canker

- One of the most commonly encountered diseases in hardwood stands in Ontario.
- Is capable of infecting more than 60 different species of trees and shrubs.
- Most commonly affected species are White and Yellow Birch, Red and Sugar Maple, Aspen, Basswood and American Beech.
- Older nectria cankers consist concentric ridges of callus tissue.
- Often referred to as "target cankers"
- Spores are released and spread by wind and rain splash.
- New infections take place through open wounds, branch stubs, or leaf scars and occur primarily on trees less than 20 years of age.
- Control is achieved primarily by the removal of infected trees.
- Complete eradication of the disease from a woodlot is virtually impossible.
- Young cankered trees should be removed and disposed of during thinning operations.
- If infection rates are more than 20% in a mature stand, regeneration with more resistant tree species is recommended.
- When infection rates are nearing 50% in young stands, sanitation cuttings are strongly recommended.
- The highest incidence rates often occur in stands growing on poor sites.

Armillaria Root Rot

- Is the most serious root disease in Ontario
- Capable of attacking, decaying and killing both deciduous and coniferous trees and shrubs in natural forests and plantations
- A soil-borne pathogen
- Unfavorable environmental conditions such as very dry weather or consecutive years of severe defoliation by insects may result in problems with armillaria.
- The first symptoms of infection are yellowing and dwarfing of foliage, followed by the death of branches in the upper crown.
- Entire foliage may die suddenly on smaller trees.
- White mycelial fans form under the bark of the roots and root collar, and are often associated with girdling of the tree.
- Dark brown-to-black shoestring-like structures, called rhizomorphs, are often found on the surface of the stump and roots and in the soil surrounding the infected trees.
- The disease usually does not progress upward into the stem for more than a 1 m (3 ft).
- The disease spreads primarily through root grafts and the production of rhizomorphs which grow outward through the soil from infected roots and stumps.
- Clusters of honey-colored mushrooms are produced at the base of infected trees and stumps in early autumn.
- Single trees or trees in small, circular pockets may die.
- Heavily infected trees experience radial growth loss, butt rot, and are prone to windthrow.
- Very difficult to control
- Good management practices that maintain a healthy, vigorously growing stand are strongly recommended.
- Although costly, the removal of old, infected stumps should be considered.
- Root systems of dead trees or stumps can supply food energy for armillaria for up to 10 years.
- Avoid all activities that would damage root systems or cause soil compaction.
- If armillaria root rot is known to be present in the woodlot, severe outbreaks of insect defoliators should be controlled.



Fruiting bodies

Sapstreak Disease

Typical stain pattern associated with sapstreak disease

- Currently causes only minor damage in southern Ontario but has the potential to become a serious problem in Sugar Maple forests
- Infected trees do not recover and are eventually killed
- Most prevalent in stands where root or stump injuries have occurred from logging, road construction, cattle trampling, or sap hauling.
- Initially signs of the disease include dwarfing of foliage.
- In subsequent years the foliage then becomes more sparse and off-colored.
- Twig and branch mortality often occurs within the crown.
- Very distinctive stain develops in the wood tissue of the roots and lower stem
- When freshly cut, the stain is greenish yellow to yellowish-tan with red flecks and appears water soaked.
- In cross-section, the stain appears to radiate outward and is bordered by a thin, intermittent, dark-green margin.
- The stain begins to darken and then fades to a light brown within minutes of the tree being cut.
- New infections occur primarily through wounds on the roots, stump, or lower portion of the stem.
- Researchers believe that feeding insects carry the spores of the disease from infected trees to fresh wounds on healthy trees.
- Minimize wounds to roots, stumps, or lower portions of the stem
- Avoid using heavy equipment in the bush when the ground is soft and root damage would result.
- Thinning operations should be conducted in the fall or winter when trees are less susceptible to infection.
- Monitor for diseased trees and remove them promptly to help control the disease.

Anthracnose

- The common name for a group of diseases caused by several closely related fungi that attack the leaves and new shoots of various hardwood trees.
- Damage is characterized by dry, scorched appearing, irregularly shaped, purplish brown areas that form along or between veins and extend outward to the leaf margin.
- Affected areas vary in size and often merge, killing the entire leaf.
- Infection may extend down the petiole and into the new, succulent shoot.
- Fungi overwinter on the ground on dead leaves or in the crown on infected twigs.
- The following spring, spores reinfect the host tree, intensifying the infection level.
- Heaviest infection rate occurs after unusually cool, wet weather during bud break.
- Single attacks are seldom harmful, mainly resulting in premature leaf drop.
- Yearly infections will cause reduced growth and may predispose the tree to other stresses.
- Repeated episodes of severe infection can cause crown dieback.
- Control treatments are not usually needed.
- Fungicide sprayed on the trees prior to bud break can offer some control.
- To protect an important maple tree, raking and destroying the infected leaves in the fall will greatly reduce the infection level the following spring.

Stem Decays

Stem decays often go unnoticed for many years. Their initial development is usually contained within the tree inconspicuously hidden behind the bark. In many cases there may not be any external signs of decay until the development of conks or fruiting bodies on the main stem.

Most stem decays enter the tree through an open wound or dead branch stub and by the time the fruiting bodies appear, decay within the tree is generally quite extensive. In many cases, there is a direct relationship between the number of conks on a tree and the amount of decay within the tree.

Once a stem decay fungus is successfully established its development cannot be controlled or stopped. The fungus primarily destroys heartwood, so there is very little effect on growth rate or sap production and infected trees can live for many years. Tree death often occurs when decay of heartwood is so extensive that it predisposes the tree to breakage during windstorms. Advanced stages of stem decay may also cause severe crown dieback. Trees bearing major stem decay conks should be removed during thinning operations to reduce the risk of wind breakage and to help prevent spread of the disease.

Table 22: **Common stem decay fungi found in sugar bushes**

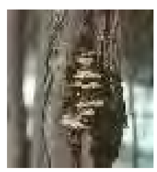
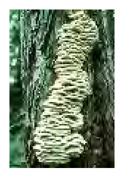
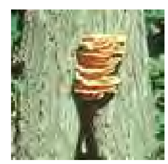
Stem Decay Fungus	Artist's Conk	Mossy Maple Conk	Tinder Conk	Northern Tooth Fungus	Sulfur Fungus
Picture of fruiting body					
Species Affected	All hardwoods	Red and Sugar Maple	All hardwoods	All hardwoods	All hardwoods esp. oaks and maples also spruce and fir
Entrance into Tree	Open wound	Branch stub or open wound	Branch stub or open wound	Open wounds and frost cracks	Open wounds
Area of Tree Affected	Initially heartwood but may spread to sapwood when decay is very advanced	Heartwood, may lead to complete hollowing of stem	Heartwood and sapwood	Heartwood	Heartwood
Management Options	Limit damage to living trees to limit potential entry points	Limit damage to living trees to limit potential entry points	Limit damage to living trees to limit potential entry points	Limit damage to living trees to limit potential entry points	Limit damage to living trees to limit potential entry points

Table 23: **Minor Diseases**

Disease	Black Tar Spot	Speckled Tar Spot	Phyllostica Leaf Spot	Coral Spot	Mossy Maze Conk
Symptom	Heavy infection of black tar spot	Heavy infection of speckled tar spot	Heavy infection	Coral spot canker damage on a young maple	Mossy maze conk fruiting bodies
Characteristics	New infections occur early in the year during periods of high humidity. Underside of leaf turns brown	New infections occur early in the year during periods of high humidity. Underside of leaf turns yellow	Also called purple eye. Produces small brown spots of dead tissue that are 6 mm (1/4 in) or less in diameter and surrounded by a purple border. Tree may take on a brown appearance and drop leaves early.	Affects previously stressed trees. Enters the tree through open wounds. Develops mostly when the tree is dormant. Amount of damage and rate of development related to level of stress.	A canker-rot causing fungus that attacks the sapwood of weakened and stressed hardwood trees. New infections generally occurring through fresh wounds. Sections of the tree above the infection often die.
Management options	None – the problem is rarely serious	None – the problem is rarely serious	None – severe infections can reduce vigour after a few years	Maintaining healthy, vigorous stands and avoiding unnecessary mechanical wounding are effective controls for this disease	Maintaining healthy, vigorous stands and avoiding unnecessary mechanical wounding are effective controls for this disease. Remove infected trees.

Coral Spot

Tar Spot

Animal Problems

Animals can cause considerable damage in a sugar bush. Domestic animal damage can be kept to a minimum by simply fencing off the woodlot. Wild animals are more difficult to control.

Domestic Livestock

- Compact soil which reduces sap production and causes deterioration and decline
- Damage caused by sharp hooves or rubbing become entrance courts for insects and diseases, especially root rotting fungi
- Young trees are trampled or eaten and saplings may be damaged or broken off
- Fence out livestock

Porcupines

- Can be a problem in the sugar bush
- Den together in small groups during the winter
- Come out during mild weather to feed, generally on the bark of trees
- Can girdle and kill branches and stems
- Will also readily feed on building materials, damaging sheds and out buildings

Squirrels, Mice, and Rabbits

- Actively feed on bark, buds, and twigs of Sugar Maple, particularly on regeneration and young saplings
- Can chew on plastic tubing in the sugar bush, sometimes causing extensive and costly damage
- Several factors have been implicated as contributing to the chewing of tubing, including, sweetness from sap, saltiness from tubing manufacture, cleaning residues, human perspiration and water remaining in portions of the lines.
- May chew the tubing simply because it is there
- May chew new salt-free tubing that has never even had sap, water, or a cleaning solution in it yet
- Wear nylon gloves when handling tubing; avoid transfer of human sweat (salts) to the tubing surface

Cavity Nesting and Feeding Birds

- Woodpeckers and sapsuckers can cause significant amounts of damage and are nearly impossible to control

Beavers

- Can cause considerable damage in a sugar bush as they flood areas to create ponds
- They will cut down trees, including Sugar Maple, for building materials and food
- Will eventually move on when they have depleted their food source
- Monitor their activity and if damage level becomes intolerable remove the animals.
- A trapper may be hired to remove beavers.

Black bears

- May cause extensive damage to mainlines and lateral lines
- They will sometimes puncture mainlines with their teeth but have also been known to completely chew and tear apart sections of mainline and lateral line.

Bear damage to a tubing installation

Climatic Stress Factors

Unfavourable weather conditions are the most common cause of non-infectious diseases associated with Sugar Maple. Severe climate conditions have been shown to initiate and intensify crown dieback events and whole tree mortality. Sugar Maples grow best in cool, moist conditions, and can be quickly and seriously damaged by insufficient soil moisture, excessive soil moisture, frost, midwinter thaw and freeze cycles, and ice and wind storms. A healthy, vigorously growing Sugar Maple tree can often withstand a single abiotic defoliation event, such as from a late spring frost, without long term lasting effects. This is the case as long as the event is not accompanied during the same growing season by some additional demanding stress factor, such as severe insect defoliation.

Climate Change

Some producers are concerned about the potential impacts of climate change on their operation. Some of the more frequent questions are: Will there be a higher frequency of severe storms and weather extremes? Will the tapping season change? And, what will happen to the maple industry as a whole? Research is only recently beginning to evaluate the potential impacts of climate change on the maple industry. Most climate change models predict a general warming trend. Preliminary research suggests that the production season is being affected. Longer-term projections suggest that some southern areas may no longer be able to produce syrup commercially in 80 to 100 years. For more information, see Appendix F.

Insufficient Soil Moisture is one of the most serious single stress factors that can have an impact on the sugar bush. Numerous studies have been conducted throughout northeastern North America on the effects of severe dry weather conditions on Sugar Maple, and have shown a direct link between very dry weather, crown dieback, and whole tree mortality.

Dry weather damage occurs when there is an insufficient amount of water in the soil to meet the needs of the trees. Damage may result from a single year of below normal precipitation or from a series of consecutive years of low precipitation. The level of injury to the trees varies within the stand depending upon the individual tree's current state of health, vigour, age, and location within the stand. The first noticeable effects of severe dry weather are wilting of the leaves, followed by discoloration of the foliage. The foliage of damaged maples usually turns yellowish or reddish brown in color, beginning at the tip or margin of the leaves and progressing until the entire leaf is dried out, brittle and dead. Premature leaf-fall commonly results. If the roots are unable to supply enough moisture to the crown of the tree, the crown may die back and decline in an attempt to bring the tree's crown and root system into a more favorable balance. Severely affected trees begin to die from the top down and from the outside in, and damage is most severe on south and southwest facing slopes. Trees stressed by severe dry weather are often invaded or attacked by weak, secondary insects and diseases. The cumulative impact of very dry weather may not be completely evident for three or four years, when the starch reserves in the root system are depleted and the full impact of the secondary organisms that have attacked the trees become apparent.

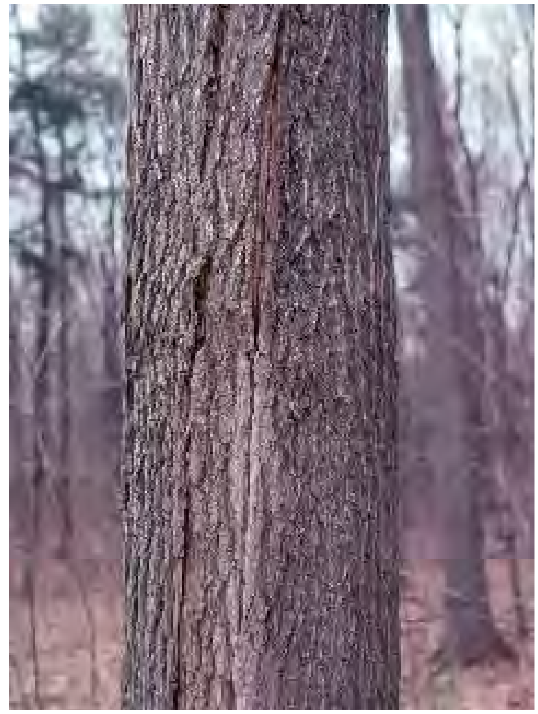
Drought

Excessive soil moisture can have adverse effects on Sugar Maple trees. Maple roots directly absorb oxygen, which is required for root development, from the soil. Maples cannot absorb oxygen from water. Therefore, when soils are saturated the tree cannot obtain the required amounts of oxygen and the tree dies. Stunted growth rates and whole tree mortality routinely occur in stands that have a prolonged period of spring or fall saturation. It is strongly recommended that low-lying stands be ditched and drained. For additional information on this topic see p 95.

Frost damage usually occurs in the winter, early spring or late summer. It is during the growing season when living tissue is affected that the most damage occurs from frost. Winter frosts can also cause extensive damage and even mortality to maple trees, especially if temperatures are excessively low. Buds, shoots, twigs and roots may be killed during the winter.

Frost damage to Sugar Maple leaves

The greatest levels of damage usually occur following a spring frost, when newly developing tissue is still soft and succulent. Frost damage causes discoloration, wilting, and death of the tender, succulent leaves and shoots. Frost-killed foliage will shrivel, turn brown, then black, and prematurely drop from the tree. Late summer frosts cause damage similar to that caused by spring frost, especially if the trees are still actively growing.



Frost crack

The term **frost crack** refers to the radial cracking or splitting of the main stem of the tree. They usually occur during the winter when there is a sudden and pronounced drop in the air temperature. The inner wood remains comparatively warm but the outer wood cools very quickly and contracts rapidly causing the wood and bark tissue to split. Frost cracks often extend from the base of the tree, upward for two to four metres (6.5 to 13 ft). Until they are completely callused over, they serve as entrance courts for various insects and diseases.

Midwinter freeze and thaw cycles cause bud, twig and branch mortality. Several days of above freezing temperatures will start the development of the buds. Then with the return of normal, below freezing temperatures, the succulent new leaves and tissues are destroyed. Also, as the buds begin to flush, the demand for water is greatly increased but the root system is usually still frozen and cannot respond to the demand. Hence, the twigs and branches quickly become dehydrated and die. Occasionally forest soils will thaw during a midwinter thaw, followed by a rapid, deep soil freeze. This can cause root breakage and subsequent reduced water uptake the following spring that will result in crown dieback.

Ice and snow storms are common events, especially across the northern range of Sugar Maple in North America. Ice or glaze damage refers to the clear layer of ice that forms when super-cooled water freezes on the surface of the twigs and branches. As the ice accumulates, the twigs and branches begin to break from the weight of the ice. The degree and amount of damage sustained by the trees depend upon forest composition, tree size and crown position, topography, and the micro meteorological conditions.

Damage to in this woodlot was caused by heavy winter snows.

Sugar Maple is less susceptible to icing damage than some other hardwoods but damage can be quite severe. Large, mature maples are damaged more than intermediate or understory trees. It has been determined from studies conducted following the January 1998 ice storm in eastern Ontario that trees that lost >75% of their crowns had very little chance for survival. Trees that sustain 50–75% crown loss were at a serious risk of dying from additional stress factors, such as very dry weather, insect defoliation or invasion by Armillaria root rot. The accumulation of wet, heavy snow, accompanied by high winds, often bends over young trees, breaks off major branches, or completely uproots trees. For more information on the 1998 ice storm please refer to Appendix E.

Leaf Scorch is a very common condition that occurs in Sugar Maple stands. It is caused by high temperatures accompanied by hot, drying winds. The leaves actually lose water faster than they can replace it. Leaf margins and the tissue between the veins die and turn brown. If the scorch condition is severe, the leaves will wilt and prematurely drop from the tree. Exposed stand edges, facing the prevailing wind, are often most heavily damaged, and young, exposed regeneration can be killed.

Sugar Maple leaves damaged by leaf scorch

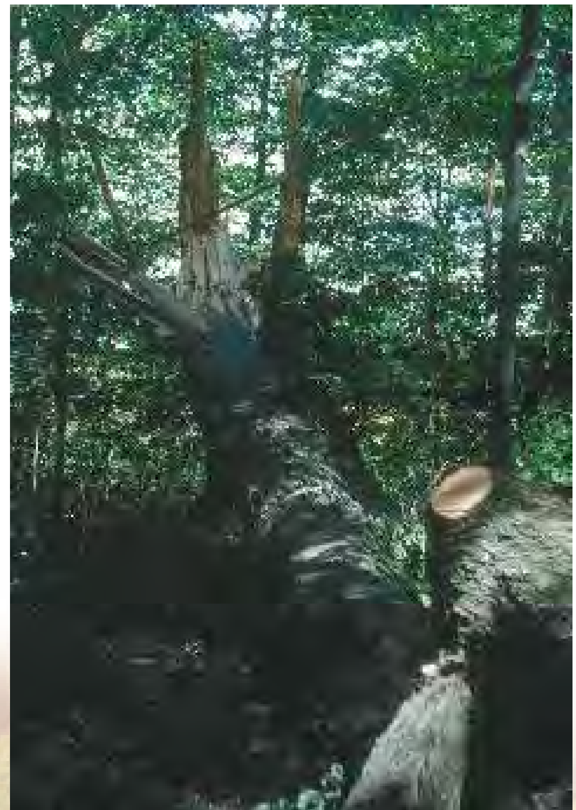
Sunscald is a condition that develops open wounds on young, smooth barked trees. It often results following thinning operations. The trees are suddenly exposed to direct sunlight causing the bark to overheat and dry out, the bark then cracks or splits exposing the inner cambium layer. Sunscald wounds are quickly invaded by secondary insects and diseases.

Damaging winds are very common throughout Ontario, and causes serious damage in numerous hardwood and conifer stands each year. Strong winds can result in defoliation, bending over of young trees, breakage of twigs, branches, or main stems, cracks and splits in main stem, damage to roots and the root collar, and the uprooting of mature trees. Wind damage can result in numerous open wounds in the stand that are quickly invaded by a variety of insects and diseases. For this reason, the full extent of the damage caused by a wind storm may

It has been determined from studies conducted following the January 1998 ice storm in eastern Ontario that trees that lost >75% of their crowns had very little chance for survival.

Trees that sustained 50 – 75% crown loss were at serious risk of dying from additional stress factors such as very dry weather or severe insect defoliation.

not be realized for several years. Hardwood stands that have been excessively opened during thinning operations are prone to wind damage. The impact of wind damage can be minimized by salvaging the downed material and properly pruning broken branch stubs.



This large tree was downed by high winds.

Mechanical Damage

When using heavy equipment in the sugar bush special care should be taken to prevent damage to the main stems and root systems of the trees. Wounds provide an entry point for insect and diseases that may result in the decline or death of the tree. Soil compaction restricts the availability and uptake of water, nutrients, and oxygen by the trees. Using a well-designed road system easily prevents most equipment-caused mechanical damage.

Mechanical damage can also result from severe wind or ice storms. When large branches or entire trees are broken off or uprooted they often damage surrounding residual trees as well. Broken branches should be properly pruned, if feasible, and uprooted trees salvaged and removed. Heavy wet snow bends over young saplings and regeneration, the majority of which will recover but some remain permanently bent.

Logging damage

Some producers are concerned about the potential impacts of climate change on their operation. Some of the more frequent questions are: Will there be a higher frequency of severe storms and weather extremes? Will the tapping season change? And, what will happen to the maple industry as a whole?

Additional Opportunities for Your Sugar Bush

10

Income or benefit received from the sugar bush in addition to maple syrup increases the profitability of the land for the producer. A main source of additional value from a sugar bush comes from the sale or use of timber products. The producer may also sell non-timber forest products for additional income.

A very significant additional opportunity for a sugar bush is visits from customers and tourists. A sugar bush lends itself well to being open to visitors. Family visits to a sugar camp become a tradition. People like to learn, experience a bit of nostalgia, and see a natural environment with healthy trees and abundant wildlife.

Today, many producers are realizing the additional financial benefits from value added opportunities in their sugar bush. Sugar bushes which offer more for the visiting public are often able to charge a premium for their maple products. Consider these value added opportunities for your sugar bush operation:

Recreational trails

Nature appreciation/viewing and photography (can be in conjunction with recreational trails)

Pancake House

Other sources of income

Your sugar bush is also a source of additional income opportunities. Examples of successes in Ontario include:

Wood sales

- Veneer logs • Sawlogs
- Pulpwood • Firewood • Spalted maple
- Niche market products like butt logs with tap hole scars

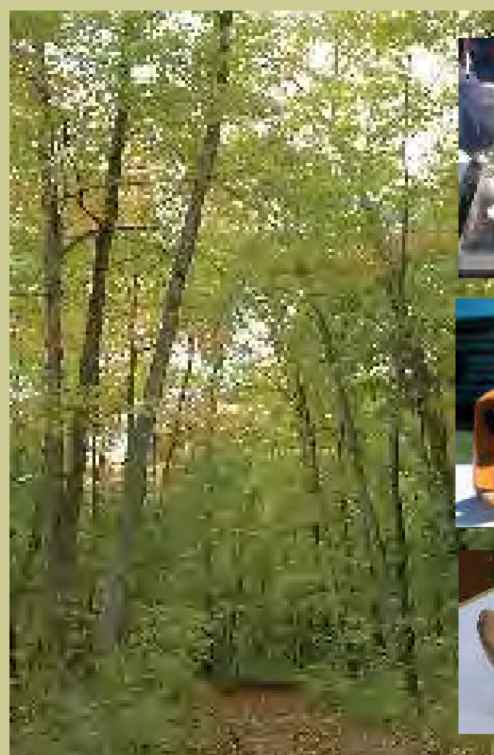
Planted Ginseng and other plants

- Ginseng (harvesting wild ginseng is never recommended as it is now an endangered species)
- Wild leeks

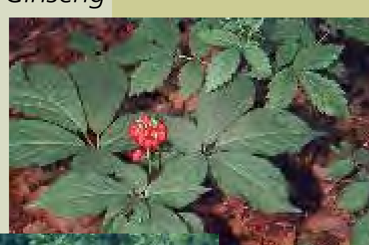
Other crops

- Honey • Wild mushrooms

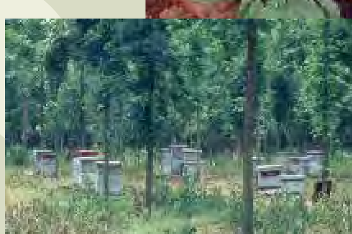
Many people gather and eat wild mushrooms. Be sure of their identification, however, as some wild mushrooms can be toxic. Consult a good field guide for more information.



Ginseng



Be careful when harvesting plants from your sugar bush. Over-harvesting can deplete the resource and many medicinal plants can be toxic if used improperly.



Beehives in orchard

11 Characteristics of a Healthy and Productive Sugar Bush

Ontario's maple industry stretches across almost the entire range of Sugar Maple. This vast area has a number of distinct climatic zones, as well as numerous soil and landform types. Throughout this area the number, scale and capacity of the many maple operations vary as well – some have great potential while others may not. Each sugar bush is unique in its own way, having its own set of circumstances that were fashioned by its past and which control its future. While some are better than others, there is great potential for many sites to support maple. Even the poorer ones can be turned around through good management. The potential of any woodlot to produce sap is bound by the forest – its structure and capability to grow maple.

This manual contains a considerable amount of information on the many inter-related factors which influence sugar bush health and productivity and while many of the principles and problems mentioned here may or may not apply to your operation, it is possible to categorize some of the most desirable features. The following table summarizes much of the information provided in the manual into three categories: ideal, acceptable and less desirable conditions or qualities which make for a good sugar bush. Ask yourself where your sugar bush 'fits' and how you might go about improving it.

Each sugar bush is unique in its own way, having its own set of circumstances that were influenced by site and historical factors.

Table 24: Biological Characteristics

	Ideal	Acceptable	Less Desirable
Past Management History	• Sugar bush historically managed with the methods described in this manual • All-aged stand structure	• Even-aged stand structure	• Cattle grazing • High grading • Rutting • Soil compaction • Poor tapping practices • Mechanical damage to trees
Species Compositon	• 75% or more Sugar and Black Maple; • Good representation of the other species in the woodlot	• >25% canopy trees are Sugar or Black Maple	• Large proportions of Red and Silver Maple • Maple is only a minor component of the forest
Tree Health	• 16 m^2/ha or more healthy trees (AGS) • 80% AGS trees with large healthy crowns and little stem defect • Taphole closure < 2 years	• 9 to 16 m^2/ha AGS trees	• < 9 m^2/ha AGS trees • < 45% of AGS have small crowns or dieback • Abundant defect • Taphole closure >3yrs
Number of Taps	• At least 150/ha (60/acre) • Abundant polewood Sugar and Black Maple (future crop trees)	• <150 but >100/ha (<60 but >40/acre)	• <100/ha (<40 per acre) • Little polewood Sugar or Black Maple
Regeneration	• Abundant Sugar and Black Maple; > 5000 seedlings/ha (2000/acre) in mature stands • Healthy representation of other species		• Little Sugar or Black Maple regeneration • Abundant other species • Abundant invasive species
Sap Sweetness	≥ 3%	< 3 but ≥ 1.5%	<1.5%

Table 25: Physical Characteristics

	Ideal	Acceptable	Less Desirable
Location	• Close to markets • Existing hydro or readily available		• Remote from major markets • Hydro difficult to access
Site	• Gentle slopes leading to a central location	• No slope at all	• Erratic slopes
Soil	• Well drained • Loamy • Fertile • pH between 5.5 and 7.5		• Rapidly or poorly drained • Coarse sandy soils • Clay soils • Infertile • Strongly acidic or alkaline
Accessibility	• Good network of forest access roads • Easily accessed from plowed roads		• Poor access in winter • No forest access roads

A

Appendix A: Glossary

aeration, soil – the process by which air in the soil is replaced by air from the atmosphere. In a well-aerated soil, the soil air is similar in composition to the atmosphere above the soil. Poorly aerated soils usually have more carbon dioxide and less oxygen than the atmosphere above the soil. Poor aeration generally occurs in the spring when soils are saturated or in compacted and rutted soils year round.

AGS (acceptable growing stock) – Trees suitable for retention in a stand. AGS trees exhibit good form and quality and are unlikely to decline in the next 10 to 20 years.

aspect – the compass direction that a particular slope faces

biodiversity – the variety and variability (in time and space) among living organisms and the ecological complexes in which they occur

canopy – the uppermost layers of branches and foliage in an individual tree or forest

canopy position – Relative position of a tree's canopy in relation to other trees. A tree is considered to have good canopy position in a stand if it is receiving full light from above and at least a little from the sides.

climate – prevailing weather conditions of an area

crop tree – a tree that is of current or future value in terms of it's ability to produce a crop of either sap or timber value. Future value is predicted to increase in these trees, very similar to the concept of AGS.

crown – the upper branched portion of a tree, from the lowest branch upward to the top of the tree

crown closure – the percentage of ground area covered by trees crowns and not open to light from above

decline – the progressive loss of vigour and deterioration of a stand of trees, often associated with a combination of stress factors such as insect defoliation and severe environmental conditions

Diameter at Breast Height (dbh) – The diameter of a tree trunk measured 1.3 metres above the ground

dieback – the dying back of portions of a tree in response to the effects of stress factors, often a survival mechanism as the tree adjusts to adverse environmental conditions

dry – see moisture regime

epicormic branching – a branch rising from a dormant bud on the stem or branch of a tree. These branches often arise when a tree is stressed, such as following excessive exposure to light after logging, or excessive canopy loss following the ice storm. Epicormic branches are less desirable than regular tree branching as they are not as solidly attached, and their location on tree stems also reduces veneer log value.

even-aged stand – a stand of trees of roughly the same age/size. Two age classes in a stand such as a mature canopy and a growing understory is also considered even-aged.

fertilization – the application of a fertilizer to a soil to supply certain elements essential to the growth of plants

fertilizer – any organic or inorganic material of natural or synthetic origin added to the soil to increase the supply of essential plant nutrients

fresh – see moisture regime

growing degree days – a system used in agriculture to determine the number of useful crop growing degree days for a given area. Growing degree days combines both daytime and nighttime temperature variations over a season, and is useful for comparing crop growth potential over large areas- such as the province of Ontario.

humus – the final breakdown product formed by the decomposition of vegetation and animal residues. Humus is generally dark in colour and is a very stable chemical compound capable of lasting in the soil for thousands of years under good soil management. Humus is beneficial in soil as it helps retain moisture and nutrients and keeps them available for tree growth.

improvement cutting – harvesting to remove inferior trees and reduce crowding in a bush to improve the overall health and quality of the stand

indicator species – plant species that convey information about the ecological nature of a site, including soil nutrient and moisture regimes, forest humus types, soil reaction, and general soil type. For example, Yellow Birch and the shrub Hobblebush are indicative of moist nutrient rich sites in central Ontario.

killing frost – A frost cold enough to kill most vegetation. At this point tree growth processes stop and leaf senescence begins if it had not already begun due to day length initiation.

larva – the immature stage, between egg and pupa, of an insect having complete metamorphosis, an immature stage differing radically from the adult

lime – In chemical terms, calcium oxide, a white substance obtained by heating limestone. In practical terms, a material containing the carbonates, oxides and/or hydroxides of calcium and/or magnesium used to neutralize soil acidity.

live crown ratio – the length of a crown as a ratio of the total height expressed as a percent.

microclimate – the climate of a small area

moist – see moisture regime

moisture regime – a system used to describe the status of soil moisture on a site over the growing season. Four broad categories are used:

> **dry** – soil moisture is lacking for adequate plant growth for the majority of the growing season. Water tables on these sites are generally beyond the reach of tree root growth, and plant growth is dependent on rainfall and temporary soil storage. Dry moisture regimes are found on rock ridges, shallow soils over bedrock and on very coarse textured soils such as gravels and coarse sands.
>
> **fresh** – soil moisture is at optimal levels fro plant growth throughout the growing season. Tree roots can either reach a deep water table, or soil texture is fine enough to retain enough moisture for plant growth.
>
> **moist** – soil moisture is excessive for most of the growing season. Moist soils have moderate to high water tables, and/or may be poorly drained.
>
> **wet** – soil moisture is extremely excessive and water table levels are so high that normal upland organic material breakdown cannot occur. Organic material instead decomposes under water form deep layers of organic muck over mineral soil. Water tables on these sites will generally be near, at or above the soil surface for much of the year.

molting – the process of shedding the exoskeleton

mottles – rust coloured spots found in soil profiles that are indicative of a seasonal water table- i.e. a water table that fluctuates throughout the year. Mottles are indicators of soil bacterial activity below the water table. The bacteria reduce iron in the soil below the water table, and when the water table subsides the reduced iron oxidizes leaving rust coloured spots.

mycorrhizae – Beneficial fungi that colonize roots, effectively extending the root system and increasing the absorption of nutrients, especially phosphorus.

nurse crop – trees or shrubs which foster or protect young trees

oviposit – to lay or deposit eggs

pH – A measure of the acidity or alkalinity of a solution. The pH scale is from 0 to 14. A pH of 7 is neutral. Values below 7 are acidic and values above 7 are alkaline.

photosynthesis – the process by which the energy from sunlight is used to synthesize carbohydrates from carbon dioxide and water in the presence of chlorophyll

prism – tool used by foresters to determine the basal area of a stand of trees. Stand composition and stand density can also be calculated from the information collected from a prism sweep.

pupa – the stage between the larva and the adult in insects with complete metamorphosis, a nonfeeding and usually an inactive stage

pupate – to transform to a pupa (insect)

slope – the steepness of the land, measured in percent or degrees from horizontal

snag tree – dead standing tree

spring frost – the average date of the last severe frost in the spring. This date generally marks the beginning of the growing season for a given area.

soil compaction – soil may become excessively packed down, particularly by heavy machinery, resulting in poor soil aeration and impeded physical growth of roots

stocking levels – a measure of whether a forest has too many, too few, or a suitable number of trees; a measure of how many and how big the trees in a forest are; used as an indicator of whether a stand needs thinning

stratification – exposing seed to cold temperatures for a period of time in order to break dormancy

topography – the configuration of the land surface, described in terms of such things as elevation and slope

transpiration – loss of water vapour by the leaves of plants

UGS (Unacceptable Growing Stock) – Trees that have a high risk of dying or declining over the next 10 to 20 years. UGS trees usually exhibit poor form and quality, and usually have a major defect such as fungal infections (as evidenced by conks), stem wounds (such as frost cracks or logging damage) or major crown dieback.

understory – a layer of vegetation beneath the main canopy of a forest

uneven-aged stand – a stand of trees of many different ages/sizes

water table – the depth to either seasonal or permanent saturation of the soil by water in a soil profile.

Appendix B: Sap Sweetness

Sap sweetness and volume are the two factors that determine sugar bush productivity and profitability. The sap sugar content of a tree will vary slightly from hour to hour and day to day. However, a tree that tests sweeter than its neighbours will normally remain consistently sweeter.

Table 26: Yield of maple syrup from a range of sap sweetness values

Sap Sweetness (BRIX)	Litres (gallons) of Sap Required to Make One Litre (gallon) of Standard Density Maple Syrup
1.0	86
1.5	57
2.0	43
2.5	34
3.0	29
3.5	25
4.0	22
4.5	19
5.0	17

As sap sweetness increases, less sap is required to produce maple syrup, resulting in more syrup produced per tap and lower costs of production. Fifty percent more syrup is produced from sap that has 3% sugar content than from sap with 2% sugar content.

Larger diameter trees can potentially produce more sap than smaller diameter trees. This is due to the volume of active sap producing wood, assuming that the active wood is roughly the first 10 cm (4 in) beneath the bark. A 30 cm (12 in) diameter tree has double the active wood area and thus double the sap production potential of a 20 cm (8 in) tree.

Sap Sugar Content and the Rule of 86

Determining the sugar content (°Brix) of sap is important when selecting crop trees and adjusting prices when selling sap. The sugar content of sap determines the amount of sap required to produce one gallon of maple syrup. When testing sap sweetness, no ice should be present in the sap and readings should be correlated to sap temperature.

When the Brix value is obtained, the Rule of 86 can be used to determine the number of litres (gallons) of sap required to make a litre (gallon) of maple syrup. The formula is as follows:

$$\text{Number of litres (gallons) of sap required to make one litre (gallon) of standard density maple syrup} = \frac{86}{\text{Brix Value (sugar content of sap)}}$$

Because the solids concentration of sap is low, the Brix value and percentage of solids are essentially the same. Prior to 1977 the standard density for maple syrup in Canada was 65.0°Brix. The legal standard density for maple syrup has increased to 66.0°Brix. This means that the percentage of sugar in a litre (gallon) of maple syrup is actually 87.2 but for practical purposes the rule of 86 is satisfactory.

Collecting sap for measuring sap sweetness

Measuring Sap Sugar Content:

The measurement of sap sugar content is an important tool in the management of sugar bushes and maple orchards. It provides the manager with an opportunity to use sap sweetness as an important criteria when thinning and harvesting operations are carried out and provides a higher likelihood of significantly upgrading average sap sweetness of the sugar bush or orchard. It is particularly appropriate when deciding which immature crop trees should be removed in thinning after the obvious undesirable growing stock (UGS) trees are already removed.

The sap sugar content of a tree can be measured using a hydrometer or a refractometer. A refractometer requires only a drop of sap and is preferred. A refractometer determines the sugar content of sap by measuring optical density. Sap sugar content of maple is not a constant value but varies with the season of the year, time of day, from day to day and even sometimes with changing weather conditions during the day (e.g. sunny to cloudy, calm to very windy, etc.).

To obtain comparable data when measuring the sap sugar content of a group of trees, sampling and testing should occur within a relatively short period of time (1-2 hours) during which weather conditions are fairly uniform. Measurements can be made anytime in the dormant season that sap is running (fall, winter and spring).

With small trees, the simplest way to obtain a drop of sap is by cutting a twig with pruning shears. With large trees, where branches cannot be reached, a taphole must be made in the trunk and the sap extracted. Usually a small drill and hammer and awl are used. A device such as a hypodermic needle, a small glue-gun needle, or a toothpick is then inserted into the hole to carry the sap away from the tree. Once sap flow has started and flowed for a brief period, a drop is collected on the refractometer.

The same method should be used to obtain all samples to be compared. Sap collected from different parts of the same tree may have different sap sugar contents. Sampling on all trees should be made at the same relative location (height and compass orientation).

To use time efficiently, a group of adjacent trees should be worked together. All sample trees in a group must be flowing adequately for comparable measurements. It is important to remember that all trees in a group will not begin or end their flow at the same time during the day.

Proper Use of a Refractometer

Proper use of a refractometer is critical to successful determination of sap sugar content. When using a refractometer, steps include:

- Refractometer must be clean, calibrated and the scale is in focus
- Temperature range of instrument must be suitable for existing temperatures
- Readings must be taken without delay to avoid evaporation from the sap sample
- Make appropriate temperature correction to Brix if refractometer is not self-adjusting for temperature
- The refractometer plate should be dried with a soft tissue, rinsed with water (preferably distilled) and dried again preferably after each reading
- Sap must be dripping at a rate of 1 drop every 8 seconds.

Appendix C: Offsetting Tap Loss Through Harvesting

C

Although harvesting operations may reduce the total number of taps in a sugar bush, the sale of sawlogs and fuelwood should help offset the loss of syrup production for a number of years depending on the quality and volume of wood harvested.

The following example documents a 2002 harvest operation in a 3000-tap sugar bush in eastern Ontario. It shows how timber sales may offset any potential loss of production for over eight years. Results will vary from sugar bush to sugar bush based on total number of taps, harvest volumes and cost of production.

The sugar bush was inventoried in the summer of 2000 and these results were used to develop a prescription for marking which identified how many and what types (size and species) of trees were to be marked for removal.

Table 27: **Sample Sugar Bush Information**

Sugar Bush Information	Comments
Total number of taps: 3000	Total taps currently installed; some potential for additional taps.
Average syrup yield/tap: 1 litre	All taps on vacuum. One litre per tap is historic average for sugar bush.
Average sugar bush yield/year: 3000 litres	Total production per year will vary depending on the season.
Sugar bush size: 18.2 Ha (45 acres)	As identified by Forest Resource Inventory maps
Currently tapped area: 13.7 Ha (34 acres)	Approximately 75% of the total sugar bush area is tapped
Sugar bush area harvested: 14.6 Ha (36 acres)	Not all of the sugar bush was thinned – tubing infrastructure, wildlife features and wetter areas amounting to approximately 20% of the stand were left unmarked.
Average number of taps/ha: 220 (89 taps/acre)	Considerable variation in tap density within the stand – some areas with high, and some areas with low density.

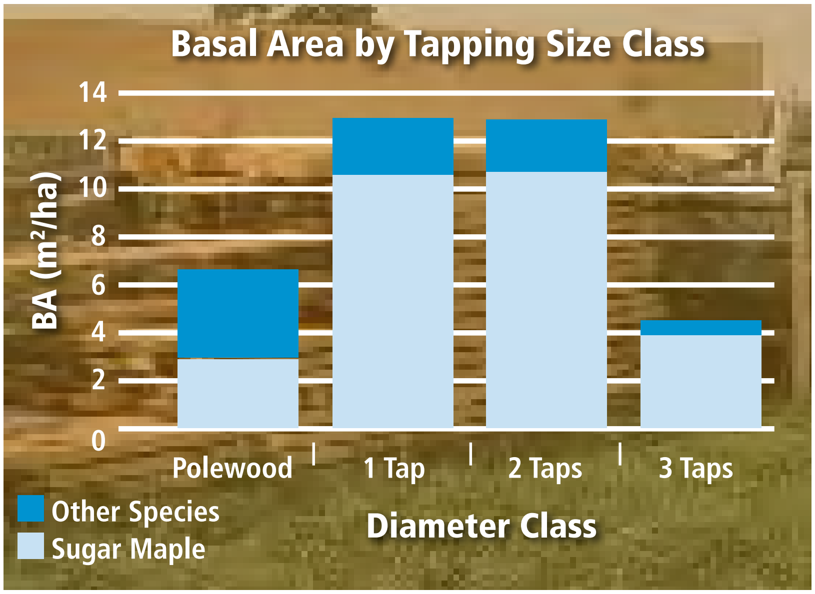
Inventory Summary

Basal Area (m^2/ha) by Species and Diameter Class

Table 28: **Inventory Summary**

Species	Size Class				
	Polewood 10 – 25 cm	1 Tap 25 – 36 cm	2 Taps 37 – 50 cm	3 Tap > 50 cm	Total BA by Species
Sugar Maple	2.7	10.6	11.0	5.3	29.6
Hemlock	1.1	1.3	0.3		2.7
Cedar		0.1			0.1
White Pine	0.1				0.1
American Beech	0.7		0.7	0.1	1.6
Basswood		0.1	0.3	0.1	0.6
Other	1.6	0.1			1.7
Total BA by Diameter Class	6.3	12.3	12.3	5.6	36.4

Figure 36: **Basal area by species and diameter class**



Species Composition: 80% maple, 20% other species

Size Class Distribution: mature stand with most of the basal area in the 1 and 2 tap size classes

Age Structure: the inventory shows that this stand is uneven-aged

Prescription Summary

- Identify and mark crop trees
- Harvest no more than 20% of the basal area
- Focus on poor quality (UGS) trees adjacent to crop trees

Below, Table 29: **Harvest Summary**

Harvest Summary Information	Comments
Total Trees Marked and Harvested: 182	148 maples, 34 other species
Total Volume Harvested: 16,929 board feet	Trees volume calculated at mill by licensed log scaler. There were no veneer quality logs from this harvest
Average Volume per Tree: 93 board feet	
Average Price Paid per 1000 board feet: $650.00	This is about average for a tapped woodlot where many of the butt logs would be a lower grade. The price represents value as determined at the mill.
Total Sawlog Sales: $11,000	This value represents the total value of sawlogs sold to the mill
Total Fuelwood/Pulpwood Sales: $2750	This value represents the total value of fuelwood harvested; some producers will use the fuelwood for their own needs.
Landowner Management Costs: $1000	The cost paid by the landowner for harvest planning, inventory and tree marking.
Total Proceeds Paid to Landowner: $5900	This value represents 50 percent of the total sales of sawlogs and fuelwood. The logger got to keep the remainder of the proceeds.

Harvesting Impact on Tapping	Comments
Total Taps Harvested: 231	Approximately 8% of the total number of taps were harvested
Average Yearly Yield (Syrup) per Tap: 1 litre	Based on average for sugar bush and region
Estimated yearly loss of syrup production: 231 litres	
Total potential sales value lost: $3807	Based on sales price of $16.5 per litre
Estimated savings in production costs : $3114	Based on average net return per litre of $3.00 (18.2% of cost per litre)
Estimated Net Return to producer lost through harvesting: $693	This figure does not include capital costs associated with equipment; these costs would remain constant regardless of thinning.

Above, Table30: **Harvesting Impact**

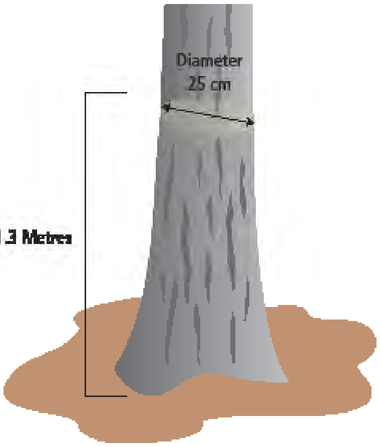
In the example above, the producer is losing approximately $693 per year in profit from the lost syrup sales associated with harvesting. When this value is compared against the proceeds from harvesting ($5900), there will not be any direct losses to production from harvesting until the 9th year (season) of production following harvest operations. In addition, the benefits of increased growth rate and improved stand health should help offset potential losses even longer.

Appendix D: Understanding Basal Area in the Sugar Bush

D

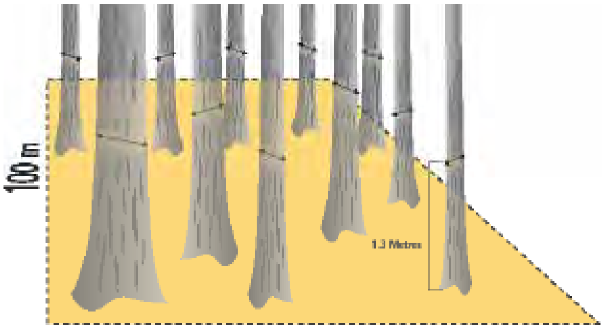
Sugar bush management involves making informed decisions about what is best for your particular operation and when it comes to deciding if your sugar bush needs thinning, there is perhaps no more important piece of information that basal area. By knowing the basal area, it is easy to determine of whether your sugar bush is overstocked, understocked or adequately stocked.

Figure 37: **Basal area by diameter at 1.3 metres**

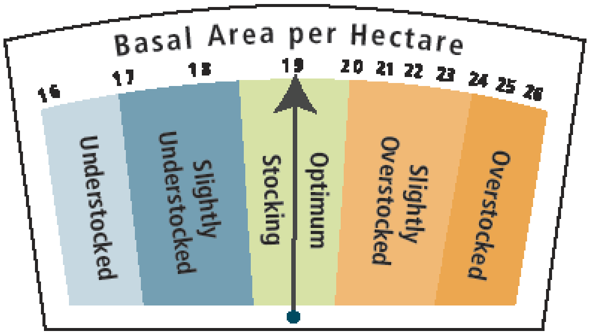


The basal area of one tree is the cross-sectional area of a stem, usually measured at breast height (1.3 m). One 25 cm (10 in) maple has a basal area of 491 square cm (.049 m^2).

Figure 38: **Basal area by hectare**



One hectare (100 m by 100 m) of your sugar bush will contain a certain number of trees, all of which have different diameters and consequently, different basal areas. By adding up all the individual basal areas of each of the trees growing in a particular hectare, you have a single number which can be compared to other sugar bushes and to what is recommended by previous forest research. This number referred to as the basal area per hectare provides a good indication of stocking and consequently whether thinning is or isn't recommended for your sugar bush.



It is generally recognized that sugar bushes with a basal area that is:

- Higher 24m^2/ha
  - the stand is overstocked for syrup production
  - thinning would be recommended
- Below 24m^2/ha but greater than 19m^2/ha
  - The stand may be overstocked and a light thinning may be necessary
  - Use caution when determining what needs to be thinned
  - Ensure that adequate regeneration is present before you thin
- At 19m^2/ha
  - The stand is adequately (well stocked) and thinning is not necessary
- Below 19m^2/ha
  - The stand is understocked and thinning is not recommended
  - Crop tree release may be appropriate for small maples (<10 cm)

It is important to note that these numbers apply to good sites for Sugar Maple production as described in this manual. Your site may be different, and if so your management prescription will need to reflect this.

Keep the following points in mind as you manage your sugar bush

- Basal area will be more difficult to use if you are not experienced in the use of a prism. Consider hiring a consultant if necessary.
- If the BA is below 24 m^2/ha (104 sq.ft/acre) it may be better to hold off or use a forest consultant to help you develop a management recommendation.
- Even if your sugar bush has a BA below this value, the trees are not evenly spaced throughout the stand and there may be smaller areas within it which have a higher BA. It is possible that these areas could use some thinning to improve health and productivity on a smaller scale.
- Ensure that your sugar bush has adequate reproduction of maple prior to thinning. If it does not harvest lightly initially to encourage regeneration.
- Never reduce the BA by more than 33% at any one time. A 33% reduction should be looked at as the maximum allowable harvest for any area of the sugar bush. Generally it is better to be more conservative during the harvests and to harvest fewer trees but harvest more frequently. A 15 to 20 percent BA reduction may be more appropriate for most sugar bushes.
- Select crop trees (ones that will not be harvested) according to the guidelines listed on page 58.
- For the uneven-aged sugar bush you can expect that the number of crop trees per hectare will be similar to that shown in Table 13, page 56, although there is some room for variability on different sites.
- Your sugar bush can be thinned all at once, or you can thin over a number of years, taking a few trees each year.
  - If you plan to thin all at once, expect that your sugar bush will need thinning every 10 to 20 years (depending on the rate of growth and how much was thinned previously). In some cases thinning can be timed to coincide with tubing upgrades.
- Maintain other species in the woodlot as well.
- Basal area will not provide an indication of the number of taps per hectare (acre).

Appendix E: Ice Storm 1998 Research

Damage from the January 1998 ice storm was widespread, affecting over 604,000 hectares (1,492,500 acres) of forest in Ontario alone. Approximately 25% of the commercial maple syrup production in Ontario was within the area affected by the ice storm. Ice storms are not uncommon in eastern North America but prior to the 1998 ice storm, little information was available on the long-term impact of such damage.

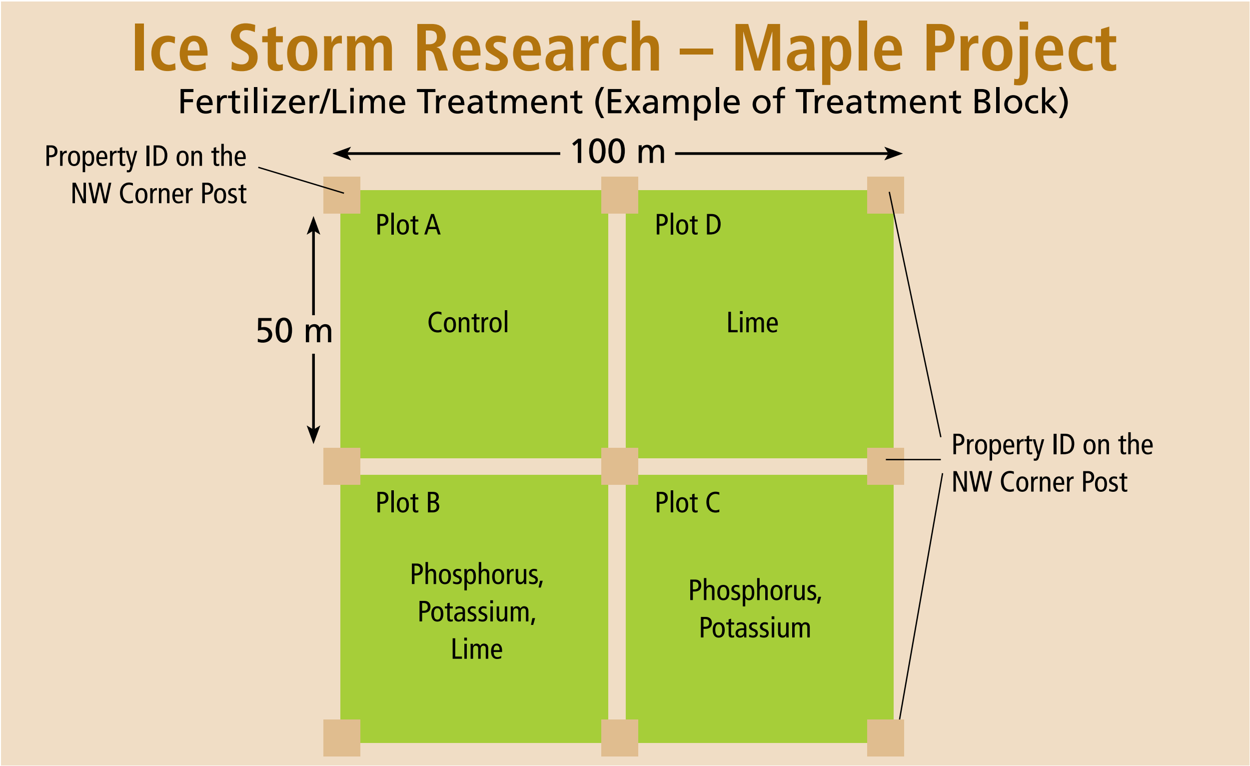
A multi-disciplinary research study, the Ice Storm Forest Research and Technology Transfer project (ISFRATT), was started in October of 1998 to address questions and concerns of landowners and maple syrup producers. The study is made up of two parts: "The Maple Experiment" and "Documenting Effects in Woodlots and Plantations". The "Maple Experiment" was designed to document the effect of crown damage caused by the ice storm.

The Maple Experiment

In 1998, 34 one-hectare blocks, covering four physiographic regions and a range of site-types and damage classes were established in active sugar bushes across the ice storm damage area in eastern Ontario. Each block was subdivided into 4 equal plots for application of fertilizer and lime treatments. Within each plot, 6 "focus" trees were selected for data collection throughout the study, totaling 24 focus trees per property.

The following treatments were applied to the blocks; Block A = control; Block B = phosphorous and potassium, each at 200 kg/ha, plus dolomitic lime at 2000 kg/ha; Block C = phosphorous and potassium, each at 200 kg/ha; Block D = dolomitic lime at 2000 kg/ha. Data was collected from the plots from 1998 to 2001 to determine the potential effects of crown damage on the factors of interest in the study. Additional funding from C-CAIRN allowed monitoring of starch reserves and growth in 2003 and of sap volume, sweetness, and taphole closure in 2004.

Figure 39: **Fertilizer/Lime Treatment**



Results

Starch Reserves, Sap Volume and Sweetness – Ice storm damage had a significant effect on root starch levels. Severely damaged trees had significantly less root starch than light or moderately damaged trees in two of the three years. Ice storm damage was found to consistently lower syrup production through 2004 in severely (>50% crown removal) and/or moderately (26-50% crown removal) damaged trees with the reductions caused by less sap sweetness and/or sap volume.

Taphole closure – Level of crown damage did not affect the rate of taphole closure. Taphole closure was quite variable.

Soil Fertility and Tree Nutrition – Results indicated that both soils and trees responded to treatment by fertilization and liming. The treatments significantly increased soil supply of added elements (P, K, Ca, Mg). Liming effectively elevated soil pH in acid soils but did not affect neutral soils. The level of ice storm damage did not significantly affect the soil or foliar response to treatment.

Ice storm damage in sugar bush

Growth of Sugar Maple – Treatments of fertilizers and vegetation control (herbicide) were applied in the spring of 1999 and increment cores were extracted and examined from each focus tree in October 2001 and again in 2003. Growth was highly variable before the storm but reached a 30 year low during the first and second year after the storm, with growth reductions increasing with increasing levels of crown damage. Treatment-related statistical differences in growth were marginal. The combination of competition control and fertilization increased growth of ice-damaged maples the most.

Near-ground Vegetation – Crown damage was found to have little effect on the distribution of near-ground plant species. Coverage of several groups of plants increased following damage but the increase was expected to be short-lived. There had been concern that the fertilizers would be taken up by the near-ground vegetation, potentially altering the near-ground vegetation community or making the fertilizer unavailable to the target trees. This was not found to be the case.

Soil Biology – Ice storm damage to Sugar Maple stands was found to result in very few negative effects on soil mesofauna (springtails, mites, etc.) and nutrient cycling processes. There was some evidence that arbuscular mycorrhizal colonization and functioning were reduced, but the productivity of Sugar Maple seedlings was not impaired.

Soil Microbes – Fertilization with lime/P/K and/or treatment with glyphosate herbicide had very little impact on soil characteristics, litter accumulation, root mass, and carbon cycling. Mycorrhizal colonization by arbuscules and mesofaunal activity were stimulated by treatments of fertilizer or herbicide, applied singly. Applications of one or the other appeared to be of equal or greater effectiveness than a combined application.

Appendix F: Potential Implications of Climate Change

F

Climate is the average pattern of weather over a period of time. The earth's climate naturally experiences change, undergoing warming and cooling trends. It is not climate change itself but the rate of change that has been an issue in recent years.

Human activity has been implicated in large increases in global temperatures over the past century. Emissions from automobiles and industry, primarily carbon dioxide, are considered as the major causes of the "greenhouse gas" phenomena. Greenhouse gases create a dome over the earth's surface trapping heat from the sun which would otherwise be reflected back out into space. This results in increased air temperatures which can have an effect on longterm climatic factors.

Climate change is very difficult to quantify due to the number of factors and variables involved. Over the past 150 years, the atmospheric concentrations of carbon dioxide have increased from 280 to 370 ppm and the overall temperature of the earth has increased by approximately 0.5ºC (32.9ºF).

The average increase in temperature in Canada over the same period has been approximately 1ºC (33.8ºF). This change appears small but is fairly significant, as average current global temperatures are only about 5ºC (41ºF) warmer than during the last ice age.

Various models have been developed to predict climate change. There is a general consensus among climate researchers that the earth is experiencing a warming trend. However, there is considerable disagreement over predictions of the full impact the greenhouse effect will contribute to future climate change. Most climate change models predict a natural warming trend with increases in precipitation. For example, the Canadian model predicts an increase of 5.2ºC (41.4ºF) by 2095 with a 5–10% increase in precipitation.

If the climate does change as predicted by some climate experts, there will be implications for the maple industry. Variables, affecting Sugar Maple growth and productivity that may be influenced by climate change include:

Seasonal dynamics

The largest increases in temperatures are predicted for the Northern Hemisphere. Winters are predicted to become milder and shorter with warmer minimum nighttime temperatures. Mild winters may result in sap that is not as sweet. Sugar Maple requires a prolonged period of temperatures below -4°C (25°F) to convert starch to sucrose. Warmer temperatures may result in sugaring seasons with a shorter number of days with freezing nights before the buds open on the trees, decreasing maple sap production.

Insects and diseases thrive under warm conditions. Because of this, an increase in temperatures could increase the severity and occurrence of problems associated with forest pests. The distribution and ranges of southern pest species could increase and pose new threats to northern hardwood forests.

Wind damage

Species migration

Climate change is predicted to have a significant impact on species composition and biodiversity within our forested areas. Changes in growing conditions may favour some tree and shrub species over others. The best growing conditions for Sugar Maple is summer temperatures ranging from 15°C to 27°C (60-80°F), with winter temperatures from -18°C to 10°C (0-50°F). Temperatures exceeding this range may allow tree species better adapted to warmer conditions to replace Sugar Maple. This may result in a gradual shift northward of both the geographic and commercial ranges of Sugar Maple.

Sugar Maple may migrate northward with increasing temperatures. Dramatic northward shifts of up to 2 degrees latitude in the geographic range of Sugar Maple are projected by the end of the 21st century. However, the specific long-term implications of climate change to Ontario's commercial maple syrup industry are unknown. Comprehensive long-term research is needed to evaluate regional changes in climate and weather and their implications. Maple producers can assist any research effort by maintaining comprehensive weather and production records for their operations.

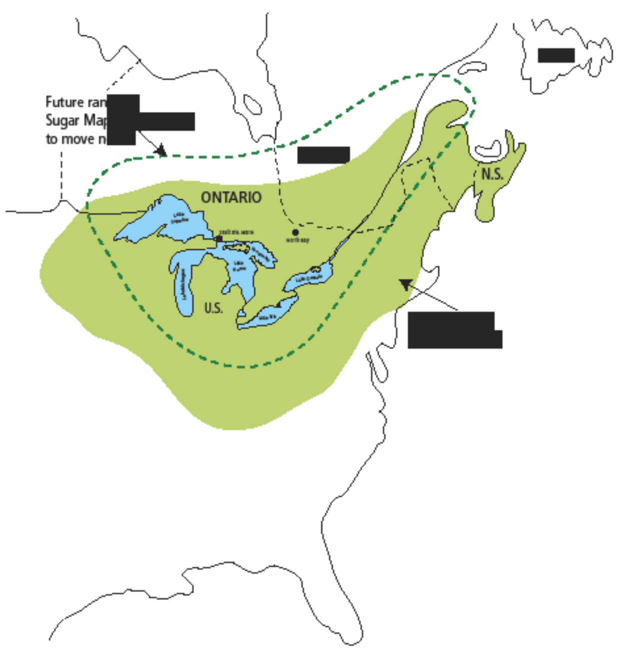


Figure 40: **Current and Future Range of Sugar Maple**

Extreme weather events

Numerous climate experts suggest climate change to be a major factor in rising sea levels, increased storm severity and increased storm frequency. Storms, particularly those with high winds or heavy ice accumulation, can significantly impact sugar bushes.

Adaptation to Climate Change

Regardless of any long-term impact of climate change on Ontario's commercial maple syrup industry, the best thing that maple producers can do is to work to improve the health and productivity of their sugar bushes. Healthy sugar bushes will have a greater resilience to the severe weather events and the negative impacts of forest pests than unhealthy sugar bushes.

Appendix G: Sources of Information and Contacts

Sources of Information and Research (Websites)

Today, almost every government and non-government agency with expertise in sugar bush management will have a web site. Use your favourite search engine to find available information or go directly to one of the websites listed below.

- **Ontario Ministry of Agriculture, Food, and Rural Affairs**
  www.gov.on.ca/OMAFRA
- **Ontario Maple Syrup Producers Association**
  www.ontariomaple.com
- **Eastern Ontario Model Forest**
  www.eomf.on.ca
- **Ministry of Natural Resources**
  www.mnr.gov.on.ca
- **Natural Resources Canada**
  www.nrcan.gc.ca
- **Canadian Food Inspection Agency**
  www.inspection.gc.ca
- **Centre Acer** – Centre de recherche de développement et de transfert technologique en acériculture
  www.centreacer.qc.ca
- **Cornell Sugar Maple Research and Extension Program**
  www.dnr.cornell.edu/ext/maple/index.htm
- **Proctor Maple Research Center**
  www.uvm.edu/~pmrc

Tips on Hiring a Consultant

Although this manual and the internet are excellent sources of information on sugar bush management, you may opt to hire a professional consultant to help guide you through some of the necessary steps (see pages 35 to 37). Consultants can help you develop your management plan, conduct an inventory of your sugar bush and even mark and thin your woodlands. Some landowners hire consultants to represent their interests when selling their timber to log buyers and loggers. In most cases, money spent on consulting fees is a sound business expense and well worth the initial investment. If you decide to go this route however, it is vitally important to find someone who is the most qualified to meet your needs.

The following points were taken from the Ontario Woodlot website (http://www.ontariowoodlot.com/), an excellent source of additional information on hiring a Service Provider (consultant) as well as many other woodlot management related topics:

- ✔ **Ask for and CHECK references**
- ✔ **Go see their work**
- ✔ **Insurance is critical**
- ✔ **Relevant experience**
- ✔ **Credentials**
- ✔ **Written agreement**

References

Allen, D.C. 1987. *Insects, Declines and General Health of Northern Hardwoods: Issues Relevant to Good Forest Management*. in: Nyland, Ralph D., ed. *Managing Northern Hardwoods: a Silvicultural Symposium*; 1986. June 23-25; Syracuse, NY. Fac. of For. Misc. Publ. No. 13 (ESF 87-002): SAF Publ. No. 87-03. Syracuse, NY: State College of New York: 252-285.

Barry, Richard. 1995. *Maple Fertilization and Sugar Yield Abs*. in: Proceedings 36th Annual Meeting North American Maple Syrup Council Conference, Kingston, ON. p. 59.

Bates, T.E. and R.W. Johnston. 1991. *Soil Acidity and Liming*. Ontario Ministry of Agriculture and Food. Factsheet. No. 91-086.

Bauce, E. and D.C. Allen. 1992. *Role of Armillaria Calvescens and Glycobius Specious in A Sugar Maple Decline*. Can. J. For. Res. 22: 549-552.

Boyce, J.S. 1961. *Forest Pathology*. 3rd. ed. McGraw-Hill Book Co., New York, NY. 152 p.

Burns, Barbara. 1999. *Essential Elements of Sugar Bush Fertilization*. Vermont Department of Forests, Parks, & Recreation. Factsheet. 4p.

Chapeskie, D. and C. Nielsen. 1999. *Interim Guidelines For The Tapping and Restoration of Sugar Bushes Affected By The Ice Storm of January 1998*. Revised February 1999. Issued cooperatively by the Ontario Ministry of Agriculture, Food and Rural Affairs and the Ontario Ministry of Natural Resources. 20 p.

Chapeskie, Dave. 2001. *Biodiversity in Sugar Bushes.* Presentation, North American Maple Syrup Conference, October 2001. Minnesota.

Chapeskie, Dave. 2003. *The Small Diameter Spile for Sap Production*. Poster. Ontario Ministry of Agriculture and Food. July 2003.

Constable, D.C. and M. J. Applejohn. 1977. *Forest Insect and Disease Surveys in The Southwestern Region of Ontario, 1977*. Dept. of Environ., Can. For. Serv., Great Lakes Forestry Centre, Sault Ste. Marie, ON. 17 p.

Coons, C.F. 1992. *Sugar Bush Management For Maple Syrup Producers*. (rev. ed.) Ministry of Natural Resources, Forest Resources Branch, Toronto, Ontario. 48 p.

Coons, C.F. 1999. *Effects of Ice Storm Damage and Other Stressors on Sugar Bush Health and Sap Productivity: Literature Review and Synthesis*. Ice Storm Forest Research and Technology Transfer. Joint Canada/Ontario Publication. 60 p.

Davis, C. and T. Myer. 1997. *Field Guide to Tree Diseases of Ontario*. Nat. Res. Can., Can. For. Serv., Great Lakes For. Centre, Sault Ste Marie, Ont. NODA/NFP Tech Rep. TR-46. 135 p.

Drooz, A.T. (ed.). 1985. *Insects of Eastern Forests*. U. S. Dept. of Agric., For. Serv., Washington, D.C. Misc. Publ. 1426, 608 p.

Godman, Richard M., Harry W. Yawney, and Carl H. Tubbs. 1997. *Acer Saccharum Arsh.- Sugar Maple*. willow.ncfes.umn.edu/silvics_manual/volume_2/acer/saccharum.htm.

Gross, H.L. 1991. *Dieback and Growth Loss of Sugar Maple Associated With Defoliation By Forest Tent Caterpillar*. For. Chron. 67: 33-42.

Hallett, Richard A., Stephen B. Horsley, Robert P. Long, Scott W. Bailey, and Thomas J. Hall. 1999. *Foliar Chemistry of Sugar Maple: a Regional View*. In: Sugar Maple Ecology and Health: Proceedings of an International Symposium. June 2-4, 1998. Warren, Pennsylvania. p. 66.

Hannah, P. 1988. *To Fertilize Or Not: A Practice That May Not Be For You*. New England Farmer. 12 (2): A4, 5.

Hendershot, W. H. 1988. *Fertilization of Sugar Maples*. The Macdonald Journal. pp. 15-16, 22.

Hendershot, W. and N. Belanger. 1998. *The Role of Soil Acidification in Forest Decline. The Effects of Acidic Deposition on Pennsylvania Forests*. 1999. William E. Sharpe and Joy R. Drohan, eds. Proceedings of the 1998 PA Acidic Deposition Conference, Vol. 1. Environmental Research Institute, University Park, PA.

Hopkin, A.A., T. Williams, R. Sajan, J. Pedlar, and C. Nielsen. 2003. *Ice Storm Damage to Eastern Ontario Forests: 1998 - 2001*. For. Chron. Vol. 79: 47-53.

Horsley, S.B., R.P. Long, S.W. Bailey, R.A. Hallet, and P.M. Wargo. 2002. *Health of Eastern North American Sugar Maple Forests, and Factors Affecting Decline*. North. J. Appl. For. 19(2): 34-44.

Horsley, Stephen B., and Robert P. Long (eds.). 1999. *Sugar Maple Ecology and Health: Proceedings of An International Symposium; 1998 June 2-4*; Warren, PA. Gen. Tech. Rep. NE-261. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 120 p.

Houston, D.R. 1981. *Stress-triggered Tree Diseases: The Diebacks and Declines*. NE-INF-41-81. Broomall, PA: U.S. Dept. of Agric., For. Serv., NE for. Exper. Stat. 36 p.

Houston, D.R. 1993. *Recognizing and Managing Sapstreak Disease of Sugar Maple*. Res. Paper NE-675. U.S. Dept. of Agric., For. Serv., NE For. Exp. Statn. 11 p.

Houston, D.R., D.C. Allen, and D. Lachance. 1990. *Sugar Bush Management: A Guide to Maintaining Tree Health*. United States Department of Agriculture Forest Service, Northeastern Forest Experiment Station, Radnor, P.A. General Technical Report NE-129. 55 p.

Howse, G.M, and M.J. Applejohn. 1991. *Forest Insect and Disease Conditions in Ontario*. For. Can., Ont. Reg., Sault Ste. Marie, ON. Survey Bulletin, Summer 1991. 31 p.

Koelling, Melvin R. and Randall B. Heiligmann. 1996. *North American Maple Syrup Producers Manual*. Ohio State Univ. Ext. Bull. 856. 178 p.

Kolb, T.E. and L.M. McCormick. 1993. *Etiology of Sugar Maple Decline in Four Pennsylvania Stands*. Can. J. For. Res. 23: 2395-2402.

Ice Storm Forest Research and Technology Transfer (ISFRATT). www.eomf.on.ca/ISFRATT

Ice Storm Forest Research and Technology Transfer. 2000. *What Have We Learned: Program Update*. Ice Storm Forest Research and Technology Transfer. Joint Canada/Ontario Publication. Issue 1. 19 p.

Lachance, D., A. Hopkin, B. Pendrel, J. Peterhall. 1995. *Health of Sugar Maple in Canada: Results From The North American Maple Project 1988-1993*. Natural Resources Canada Canadian Forest Service information Report St-X-10. 27 p.

Laing, F.M. 1983. *At The Root of The Sugar Maple – Mycorrhizas*. Maple Syrup Journal. Dec. 1983: 13.

Lautenschlager, R.A., John H. Pedlar, and Cathy M. Nielsen. 2003. *Ice Storm Damage: Effects of Competition and Fertilization on Near-ground Vegetation*. For. Chron. 79 (1): 54-61.

Lautenschlager, R.A., John H. Pedlar, John A. Winters, and Cathy M. Neilsen. 2003. *Ice Storm Damage: Effects of Competition and Fertilization on The Growth of Sugar Maple Trees*. For. Chron. 79(1): 63-69.

Liu, X. D. Eilsworth and M. Pyree. 1997. *Leaf Nutrition and Photosynthetic Performance of Sugar Maple. (Acer Saccharum) in Stands With Contrasting Health Conditions*. Tree Physiology. 17: 169-178.

Long, Robert P., Stephen B. Horsley, and Paul R. Lilja. 1997. *Impact of Forest Liming on Growth and Crown Vigor of Sugar Maple and Associated Hardwoods*. Can. J. For. Res. 27: 1560-1573.

Long, Robert P., Stephen B. Horsley, and Paul R. Lilja. 1999. *Impact of Forest Liming on Growth, Vigor, and Reproduction of Sugar Maple and Associated Hardwoods.* In: Sugar Maple Ecology and Health: Proceedings of an International Symposium; 1998 June 2-4; Warren, PA. Gen. Tech. Rep. NE-261. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. pp. 55-58.

Manion, P.D. 1991. *Tree Disease Concepts*. Prentice-Hall, Englewood Cliffs, NJ. 416 p.

Matineau, R. 1984. *Insects Harmful to Forest Trees*. For. Tech. Rep. 32. Ottawa, ON.: Multiscience Publishers Ltd. and Can. For. Serv. 261 p.

MacIver, D.C., M. Karsh, N. Comer, F. Klassen, H. Auld, and A. Fenech. 2006. *Atmospheric Influences on the Sugar Maple Industry in North America. Adaptation and Impacts Research Division (AIRD)*, Environment Canada. Occasional Paper #7. pp.21

Millers, I., D.S. Shriner, and D. Rizzo. 1989. *History of Hardwood Decline in The Eastern United States*. U.S. Dept. Agric., For. Serv.. Gen. Tech. Rep. NE-126.

Ministère des Ressources naturelles. 2000. *Management of Ice Storm Damaged Stands*. Charlesburg, Québec. Québec Min. Ress. Nat. 65 p.

Mohammed, Gina H. 1999. *Non-timber Forest Products in Ontario: An Overview*. Ontario Forest Research Institute and Ontario Ministry of Natural Resources. Forest Research Information Paper No. 145. 71 p.

Morrow, R.E. 1976. *Sugar Bush Management*. Inf. Bull. 110. Ithaca, NY: New York State College of Agric. and Life Sci., Cornell University. 19 p.

Myren, D.T. (ed.). 1994. *Tree Diseases of Eastern Canada*. Nat. Res. Can., Can. For. Serv., Sci. Sustain. Dev. Dir., Ottawa, ON. 159 p.

Natural Resources Canada. 2003. *Climate Change*. www.cfl.scf.rncan.gc.ca/ecosys/issues/clim_chg_e.asp

Nearing, Helen and Scott Nearing. 1970. *The Maple Sugar Book: Together with Remarks on Pioneering as a Way of Living in the Twentieth Century*. Schocken Books. New York. 273 pp.

New Brunswick Ministry of Natural Resources & Energy. 1988. *A Guide to Sugar Bush Thinning 1988*. Fredericton, NB. NB Min. of Nat. Res. & En. 15 p.

Noland, Thomas L. 2003. *1998 Ice Storm Impact on Sugar Bushes of Eastern Ontario*. For. Chron. 79(1):75-81.

New England Regional Assessment Group (NERA). 2001. *Preparing For A Changing Climate: The Potential Consequences of Climate Variability and Change*. New England Regional Overview, U.S. Global Change Research Program, 96 pp., University of New Hampshire.

North American Maple Syrup Council Manual. **(Draft). 2005.** Ohio State University. Unpublished Manuscript.

Ontario Maple Syrup Producers Association. 1999. *Ontario Maple Orchard Directory*. 140 pp.

Ouimet, R. and C. Camiré. 1995. *Foliar Deficiencies of Sugar Maple Stands Associated With Soil Cation Imbalances in The Quebec Appalachians*. Canadian Journal of Soil Science. 75: 169-173.

Payette, S., M.J. Fortin, and C. Morneau. 1996. *The Recent Sugar Maple Decline in Southern Quebec: Probable Causes Deduced From Tree Rings*. Can. J. For. Res. 26: 1069-1078.

Richardson, Mark. 2003. *Principles and Practices of Sugar Bush Management. Caring For Your Land Workshop Series*. Eastern Ontario Model Forest.

Rose, A.H. and O.H. Lindquist. 1982. *Insects of Eastern Hardwood Trees*. (Rev. ed. 1997. K. Nystrom) Nat. Res. Can., Can. For. Serv., For. Techn. Rep. 29, Ottawa, ON.

Schooley, J. 2003. *Cost of Production of 1 Acre of Ginseng in Ontario*. OMAF Ginseng Series. Ontario Ministry of Agriculture and Food. http://www.gov.on.ca/OMAFRA/english/crops/facts/gincop.htm

Sharpe, W.E., B.R. Swistock, and T.L. Sunderland. 1999. *Soil Acidification and Sugar Maple Decline in Northern Pennsylvania*. in: Proceedings of the 1998 Pennsylvania Acidic Deposition Conference, Vol. 1. Environmental Resources Research Institute, University Park, PA. pp 191-194. and Maple Syrup Digest. Feb. 1996: 32-35.

Skilling, D.D. 1964. Part 5. *Ecological Factors Associated With Maple Blight*. Univ. Wisconsin Res. Bull. 250. P. 115-129.

Syndicat des producteurs de bois de la Beauce. 1999. *Guide to Sugar Bush Management*. Simon Rodrigue, ed. Ville de Saint-Georges, Quebec.

Taylor, E.P and R.K. Jones. 1986. *Guide to Species Suitability for Site Regions 6e and 7e – using field recognizable soil properties*. Addenda 1 to Ontario Institute of Pedology Publication 85-3, University of Guelph.

Timmer, Vic R., Yuanxin Teng, and John Pedlar. 2003. *Soil and Leaf Analysis of Fertilized Sugar Maple Stands After Ice Storm Damage*. For. Chron. 79(1):99-105.

U. S. Department of Agriculture, Forest Service. 1985. *Insects of Eastern Forests.* Misc. Publ. No. 1426. Washington, DC: U.S. Dept. of Agric., For. Serv. 608 p.

Visser, S. and R.A. Lautenschlager. 2001. *Effects of Ice Storm-related Crown Damage of Sugar Maple on Soil Biology*. Ice Storm Forest Research and Technology Transfer Project.

Visser, S. and R.A. Lautenschlager. 2001. *Soil Microbial Response to Fertilizer and Herbicide Treatment of Ice Storm Damaged Sugar Maple Stands*. Ice Storm Forest Research and Technology Transfer Project.

Walters, R.S. and A.L. Shigo. 1978. *Tapholes in Sugar Maple: What Happens in the Tree*. Gen. Tech. Rep. NE-47. Upper Darby, PA. U.S. Dept. of Agric., For. Serv, NE For. Exper. Stat. 12 p.

Wargo, P.M. 1988 (rev.). *Judging Vigor of Deciduous Hardwoods*. Agric. inf. Bull. 418. Washington, DC: U.S. Department of Agriculture, Forest Service. Agriculture information Bulletin. 16 p.

Wargo, P.M. and D.R. Houston. 1974. *Infection of Defoliated Sugar Maple Trees by Armillaria Mellea*. Phytopathology. 64: 817-822.

Westing, A.H. 1996. *Sugar Maple Decline: An Evaluation*. Econ. Bot. 20:196-212.

Wilmot, T.R., D.S. Ellsworth and M.T. Tyree. 1995. *Relationships Among Crown Condition, Growth and Stand Nutrition in Seven Northern Vermont Sugar Bushes*. Can. J. For Res. 25: 386-397.

Wilmot, Timothy. 2000. *A Survey of Sugar Maple Nutrition in Vermont and its Implications for the Fertilization of Sugar Maple Stands*. Maple Syrup Digest. Oct. 2000: 18-21.

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