Report of a Forestry Mission to Scandinavia
Report of a
Forestry Mission to Scandinavia

by
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March 1990
Funding for this publication was provided by the Canada-British Columbia Forest Resource Development Agreement—a five year (1985-90) $300 million program cost-shared equally by the federal and provincial governments.

**Canadian Cataloguing in Publication Data**

Main entry under title: Report of a forestry mission to Scandinavia

(FRDA report, ISSN 0835-0752 : 156)

Issued under Canada-BC Forest Resource Development Agreement.

Co-published by B.C. Ministry of Forests and Northern Interior Lumber Sector, Council of Forest Industries of B.C.

“Canada/BC Economic & Regional Development Agreement.”

Includes bibliography: p.

ISBN 0-7726-1288-9


SD568.B7R46 1991 333.751'09711 C01-092097-4

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This is a joint publication of Forestry Canada and the British Columbia Ministry of Forests.

Produced and distributed by the Ministry of Forests, Research Branch.

For additional copies and/or further information about the Canada-British Columbia Forest Resource Development Agreement, contact:

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EXECUTIVE SUMMARY

A 1989 Forestry Mission to Scandinavia comprised of representatives from Forestry Canada, the British Columbia Ministry of Forests, and the Northern Interior Lumber Sector of the Council of Forest Industries of British Columbia had two purposes.

The first purpose was to examine Scandinavian developments in the following areas:

- Forest management programs;
- Land use and environment issues; and
- Long-term strategic plans and visions of forests of the future.

The second purpose was to make recommendations for British Columbia based on the Scandinavian experience.

This report reviews the history of Scandinavian forestry, describes major Scandinavian forestry institutions, details the regulatory framework within which Scandinavian forestry operates, and describes the Scandinavian silviculture regime.

While Scandinavian forests have been used for almost 700 years, the "golden age" of forestry did not begin until after World War II. The thrust of Scandinavian forestry legislation is to use timber growing capacity fully through the entire life of the stand. The legislation, which requires clearcutting, applies equally to public and private land. The majority of forest land is privately owned, and the majority of that is held by individuals.

There is a strong forestry ethic among those who work in the forest as well as within the general public.

About 57% of each of Sweden and Finland's total area is working forest, compared to only 29% in British Columbia. The Scandinavian people make heavy use of their forests for recreation. This exposure to the forests, combined with significant private ownership, leads to strong support for forestry operations. Nevertheless, the use of exotic tree species, preservation of mountain forests, and concern about certain forestry operations such as peat drainage, ditching, and fertilization are key environmental concerns. The use of herbicides for forestry is virtually non-existent because of environmental pressures in the past, but this loss of a management tool is not as serious a situation as it might be in British Columbia because the Scandinavian brush problem is not as significant. Clearcutting was also an issue about 10 years ago but today seems to be generally accepted by the public.

Most of the working forest is a managed forest, young and vibrant, suitable for intensive silviculture. There is little old growth left. The silviculture techniques used are well-known to British Columbia foresters, but the extent of their application is greater. The regime consists of clearcutting, regeneration primarily by planting, cleaning, thinning, and fertilization. Thinning is particularly important to provide much-needed wood flow and can be justified financially because of the high cost of alternative wood sources.

Timber growth under this regime is exceeding expectations. Money saved in transporting final products, because of the proximity of markets, can be spent in the forest. This regime cannot be applied in its entirety in British Columbia at this time because we must deal with a preponderance of overmature, unmanaged forests, relatively far from the markets for our final products.

The major causes of forest damage are animal browse, airborne emissions, and soil acidification, although insect attacks were epidemic in the 1970's.

Up-to-date timber inventories are conducted by organizations independent of the government and forest owners. Scandinavians use the concept of potential cut based on fibre yield rather than allowable annual cut based on utilization standards, and determine it from modelling which is updated every 5 to 10 years.

- The total volume of growing stock is the largest it has ever been and continues to increase.
- Annual growth rates are the highest they have ever been and continue to increase.
- The annual cut is less than the potential cut and has been for some time.
- The demand for wood exceeds the annual cut, the difference being made up with imports, which are often less expensive than the incremental domestic supply.

Forestry education and training in Scandinavia are both extensive and long-standing. Today, few work in Scandinavian forests without training. This education system has provided Scandinavia with a skilled and supportive work force.
Scandinavians constantly plan their forests of the future. Recent plans call for increased timber production while recognizing multiple uses of the forests.

Mission members have concluded that the following key recommendations will significantly improve forest management in British Columbia:

1. **Education:** We must improve the education and knowledge base of the general public, forestry workers, and land owners not presently contributing to the working forest.

   The general public in Scandinavia have greater confidence in forestry than their counterparts in British Columbia. British Columbia should consider a forestry curriculum in the compulsory schooling program and increased communications between the forestry community and the adult population, such as field tours, open houses, and advertising, combined with appropriate written and audio visual material.

   All forestry workers should be given at least some training. There must be better coordination between technical and professional courses to permit technicians to advance. Professional courses must be more field oriented and provide a better understanding of integrated resource management. A comprehensive continuing education program must be developed for all levels.

   While British Columbia does not have the same extent of private ownership as Scandinavia, private landowners should be encouraged to keep forest land in forest production possibly through tax incentive schemes and a comprehensive extension service provided by both government and industry. If such programs fail, it may be necessary to legislate standards of forest practise on private land.

   The fundamental goal of such an education program should be to imbue all British Columbians with a strong forestry ethic.

2. **Forest Resource Goals:** We must establish what we expect from the forests by setting resource goals for timber production as well as all other uses of the forest.

   These goals should reflect increasing timber production while at the same time make appropriate allowances for other uses of the forest.

   Goals for timber production and production methods should reflect trends in manufacturing capabilities and market demand, recognizing that flexibility is a key element for our future forests.

   British Columbia should focus more on environmentally sound forest management practices than on alienating more of the working forest as a means of preserving the environment.

3. **Forest Management Techniques:** Emphasis must continue to be placed on increasing wood quantity (growth rates) and quality (growth traits) through appropriate intensive management programs. Tree improvement and fertilization programs should be expanded. A program to assess herbicides and their alternatives should begin immediately.

   All timber production programs must consider impact on other forest resources and be developed to cost effectively minimize such impacts.

   To accomplish these goals, inventories of all forest resources must be substantially improved through expansion and updating, and significantly more work must be done in growth and yield modelling of managed forests.
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1 INTRODUCTION

Forest management is continually evolving — today, driven as much by social as by scientific considerations. Public interest in our forests has never been higher and the demands put on our limited forest resources have never been greater. Society expects forest managers to provide wilderness and recreation opportunities, protect fish and wildlife habitat, maintain high water quality and produce commercial timber at a rate that will sustain the world's highest standard of living.

British Columbia's forest resources are rich and abundant, but it is clear even these great resources cannot satisfy the many demands placed upon them unless there is superior management. While demanding much from our forest managers, the public, and particularly certain interest groups, often express doubt about the validity of our forest management practices.

Our forest managers must be knowledgeable about forestry practices in other jurisdictions. We can learn from their successes and failures. This is especially true of those jurisdictions whose forest resources and conditions resemble those of British Columbia, yet whose forest use evolved earlier than that of British Columbia.

Scandinavia's boreal forests closely resemble much of British Columbia's interior forests, yet they have been in use and under management much longer. Much has already been learned from Scandinavia and applied in British Columbia. But, the perception held by some is that Scandinavia is still ahead of British Columbia in forest management techniques.

In light of this, a tripartite group of representatives from the British Columbia Ministry of Forests, Forestry Canada, and the Northern Interior Lumber Sector participated in a Forestry Mission to Sweden and Finland from 26 May to 11 June 1969. Appendix I contains a list of Mission members and the Mission itinerary.

The Mission had two main purposes:

1. To examine Scandinavian developments in:
   • forest management programs;
   • land use and environmental issues; and
   • long-term strategic plans and visions of forests of the future.

2. To make recommendations for British Columbia based on the Scandinavian experience.

FIGURE 1. Large lodgepole pine stock grown in the SCA Boglundet Tree Nursery.
2 COMPARATIVE STATISTICS

Remarkable similarities exist between Scandinavian forests and those of British Columbia, but there are also fundamental differences. When considering recommendations made in this Report it is important to have some basic facts in mind (Table 1).

TABLE 1. Comparative statistics for Sweden, Finland, and British Columbia

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Finland</th>
<th>British Columbia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>8.4 million</td>
<td>4.9 million</td>
<td>3.1 million</td>
</tr>
<tr>
<td>Total forested area</td>
<td>26 million ha</td>
<td>22 million ha</td>
<td>52 million ha</td>
</tr>
<tr>
<td>Working forest</td>
<td>23 million ha</td>
<td>19 million ha</td>
<td>28 million ha</td>
</tr>
<tr>
<td>Forest ownership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td>26%</td>
<td>28%</td>
<td>94%</td>
</tr>
<tr>
<td>Companies</td>
<td>24%</td>
<td>8%</td>
<td>5%</td>
</tr>
<tr>
<td>Individuals</td>
<td>50%</td>
<td>64%</td>
<td>1%</td>
</tr>
<tr>
<td>Standing volume</td>
<td>2700 million m³</td>
<td>1700 million m³</td>
<td>8900 million m³</td>
</tr>
<tr>
<td>Species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruce</td>
<td>47%</td>
<td>37%</td>
<td>23%</td>
</tr>
<tr>
<td>Pine</td>
<td>38%</td>
<td>45%</td>
<td>19%</td>
</tr>
<tr>
<td>Deciduous</td>
<td>15%</td>
<td>18%</td>
<td>4%</td>
</tr>
<tr>
<td>Others</td>
<td>0%</td>
<td>0%</td>
<td>54%</td>
</tr>
<tr>
<td>Allowable (or potential) annual cut⁴</td>
<td>90 million m³</td>
<td>67 million m³</td>
<td>74 million m³</td>
</tr>
<tr>
<td>Current annual harvest⁴</td>
<td>67 million m³</td>
<td>54 million m³</td>
<td>74 million m³</td>
</tr>
<tr>
<td>Annual production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood products</td>
<td>12 million m³</td>
<td>9 million m³</td>
<td>39 million m³</td>
</tr>
<tr>
<td>Pulp</td>
<td>11 million tonnes</td>
<td>9 million tonnes</td>
<td>7 million tonnes</td>
</tr>
<tr>
<td>Paper</td>
<td>9 million tonnes</td>
<td>8 million tonnes</td>
<td>3 million tonnes</td>
</tr>
<tr>
<td>Forest employment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>142 000</td>
<td>100 000³</td>
<td>87 000</td>
</tr>
<tr>
<td>Indirect</td>
<td>70 000</td>
<td></td>
<td>174 000</td>
</tr>
</tbody>
</table>

⁴ Sweden and Finland use the concept of potential, rather than allowable, annual cut. British Columbia figures for allowable cut and annual harvest are for Crown-regulated lands only. The cut from private lands not part of a regulated unit in British Columbia was 13.7 million m³ in 1989.

³ This is a combined estimate for direct and indirect forest employment.

What are some of the significant points that can be drawn from these statistics?

First, about 29% of British Columbia is working forest, while the working forest comprises 57% of each of Sweden and Finland. This has important implications for land use decisions and how people view the forest.

Second, more than 70% of forests in Sweden and Finland are privately owned, whereas in British Columbia only about 6% of forest land is in private ownership. This ownership pattern affects public regulation of forestry and industrial structure, as well as land use and perceptions of the forest.

Third, the allowable annual cut per unit area of working forest is lower in British Columbia than in either Sweden or Finland, even though British Columbia has substantially more standing timber volume. This is, in part, a function of forest structure and silviculture treatments.
3 HISTORICAL OVERVIEW

Scandinavia has a long forest history, dating back almost 700 years. The forests were first used for fuelwood and were subjected to clearing for farmland. As early as the late 13th century, limitations were placed on the right to clear forest.

By the 16th century, Finland was exporting firewood and axe-hewn timber beams. At about the same time, Sweden was taking steps that would continue into the early 19th century to establish oak plantations to meet naval requirements.

Sometime in the latter part of the 16th century, and continuing for almost three centuries, huge demands were put on the central Swedish forests for charcoal to supply iron works. It is estimated that charcoal production consumed 4 to 5 million m³ per year during its peak, affecting over the period of the iron works between 3 and 4 million hectares of forest land.

The advent of steam power and a move away from the mercantile philosophy ushered in an established sawmilling and paper industry in the early and late 19th century respectively. The rejection of mercantilism also led to a massive sell-off of public lands to individuals, mostly farmers. By the early 20th century, forest companies had purchased significant tracts of forest land from farmers, but that practice was severely limited soon thereafter and has remained limited ever since.

When the forest industry began a rapid expansion in the mid-1800's, Scandinavian society changed from an agrarian society to an industrial one. In many areas the forests had been depleted, and the regulatory efforts aimed at protecting rather than managing the timber resource were not equal to the demands that would soon be placed on the forest. Fortunately, the growth in forest industries during the latter half of the 19th century was accompanied by a growing awareness of the need to manage the forests.

The first forestry laws of any significance were introduced in Finland in 1886 and in Sweden in 1903. At about the same time, government organizations were established to manage public forests and to monitor activities on private forests. Public interest in forest management was evidenced by a new and growing folk movement — tree planting.

The initial laws were aimed at preventing the devastation of forests by requiring regeneration after harvesting. These were followed in the early 20th century with laws prohibiting the felling of young forests except for the purposes of thinning.

Despite a long history of forest use, and apart from certain notable exceptions, Scandinavia has practised forest management for a relatively short period. The "golden age" of forestry did not begin in Scandinavia until after World War II, about the same time the rapid expansion of the forest industry in the Interior of British Columbia got underway. Its impact is demonstrated by the enormous increases in growth rates and growing stock since 1952, as shown in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2. Increase in Sweden's growing stock and increment, 1952–1982</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Increase</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Growing Stock (total m³)</td>
</tr>
<tr>
<td>Growing Stock (m³/ha)</td>
</tr>
<tr>
<td>Increment (m³/year)</td>
</tr>
<tr>
<td>Increment (m³/ha/year)</td>
</tr>
</tbody>
</table>

These gains in growing stock and increment were earned in only thirty years because of modern forest management. This is a key lesson to be learned. The Scandinavian experience tells us that success in forest management can be achieved in a short period.
Forest management is the responsibility of four major sectors in Sweden and three in Finland (Figure 2). In Sweden, those sectors are the National Board of Forestry and Domän (a state-owned forest company) on behalf of the state, the private forest owners, and the forest companies. Finland has only three sectors because it does not have a counterpart to Domän.

![Pie charts showing forest land ownership in Sweden, Finland, and British Columbia.](image)

* In Sweden and Finland, includes land owned by local authorities and parishes.

**FIGURE 2.** Comparison of forest land ownership in Sweden, Finland, and British Columbia.

### 4.1 The National Board of Forestry

In Canada, the two senior levels of government (federal and provincial) each play a role in forestry, although primary responsibility for forest management rests with the provinces. Scandinavian countries have only one senior level of government. Its forestry administration, the National Board of Forestry, most closely resembles the provincial Ministries of Forests. The main duties of the National Board are:

- application of the Forestry Act;
- extension services for forest owners and others;
- information to other authorities and organizations, schools, the general public, and visitors from abroad;
- distribution of state grants and subsidies for silviculture, road construction, and other forest management activities;
- inventory and development of forestry plans; and
- participation in community planning, forecasting, and keeping statistics.

Sweden's National Board of Forestry employs about 2400 full-time and 4200 part-time employees, compared to approximately 3500 FTE's in B.C.'s Ministry of Forests. The main differences between the National Board of Forestry and B.C.'s Ministry of Forests are:

- the National Board regulates forest practises on private as well as public lands (although private land regulation is expected in British Columbia soon);
- the National Board emphasizes extension work to private owners whereas the Ministry emphasizes integrated resource management; and
- the National Board does not administer development or harvesting programs such as the British Columbia Small Business Forest Enterprise Program.
4.2 Domän

Domän, the state-owned forest enterprise in Sweden, manages all forests belonging to the Crown, amounting to 3.7 million hectares, or about one-fifth of Sweden’s productive forests and twice the forest area managed by the next largest owner. In addition to harvesting 6.7 million m³ per year, Domän operates several sawmills, provides wood to state-owned pulp mills and manages agricultural land, rental housing, and several other ventures. Although state-owned, the forest management practices of Domän are subject to the Forestry Act and are overseen by the National Board of Forestry.

4.3 Private Owners

Although Domän is the largest single owner of forest land in Sweden, it is individual owners who manage the majority of forest land in both Sweden and Finland.

There are some 200,000 individual forest owners in Sweden and almost 300,000 owners in Finland (Figure 3). About 85,000 of the Swedish forest owners, owning some 5.4 million hectares of forest land, are members of one of 12 forest owners’ associations, the largest having about 25,000 members. Finland has only one main forest owners’ association, which has approximately 125,000 members.

The main functions of the associations are to:

- conduct roundwood sales;
- conduct felling and silvicultural activities;
- process the timber of their members and market the resulting manufactured products; and
- provide information and further education for their members.

FIGURE 3. In stark contrast to British Columbia, much of the Scandinavian forest is divided into many small parcels owned by hundreds of thousands of individuals.
4.4 Forest Companies

While there are many forest companies in Scandinavia, the industry is dominated by a very few world-class operations. Of the world's fifty largest forest products companies in 1989, three were Swedish (Stora Group 5th, SCA 17th, and MoDo 20th) and four were Finnish (the highest ranking being Kymmene at 27th). By comparison, six Canadian companies made the list, the highest being Noranda Forest at 14th. MacMillan Bloedel, British Columbia's largest company, was 23rd. Table 3 provides a comparison of industry size.

**TABLE 3. Comparison of forest industry size between Sweden, Finland, and British Columbia**

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Finland</th>
<th>British Columbia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawmills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>annual production</td>
<td>300</td>
<td>175</td>
<td>216</td>
</tr>
<tr>
<td>(million m³)</td>
<td>11.4</td>
<td>7.5</td>
<td>37</td>
</tr>
<tr>
<td>Panel Board Mills*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number</td>
<td>21</td>
<td>36</td>
<td>25</td>
</tr>
<tr>
<td>annual production</td>
<td>1.7</td>
<td>1.2</td>
<td>2</td>
</tr>
<tr>
<td>(million m³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulp and Paper Mills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number</td>
<td>112</td>
<td>77</td>
<td>24</td>
</tr>
<tr>
<td>annual production</td>
<td>17.4</td>
<td>16.5</td>
<td>10</td>
</tr>
<tr>
<td>(million tonnes)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* includes plywood, veneer, particle board, and similar products

Three features of the Scandinavia forest industrial structure are not found in British Columbia. First, Sweden operates state-owned manufacturing plants. Second, individual forest owners in both Sweden and Finland have joined together in forest associations which operate significant manufacturing facilities. Third, two large and unrelated Finnish companies (Kymmene and Oy Tampella) jointly own and operate a timber supply company called Tehdaspuu Oy. Tehdaspuu provides 11.4 million m³ of wood per year to its two shareholders. It also manages 450,000 ha of forest land owned by its shareholders, from which it obtains 9% of its total annual wood requirements.

4.5 Other Institutions

Additional organizations play an important role in Scandinavian forest management. Among them are trade associations having purposes similar to British Columbia forest industry trade associations. Research and education institutions which play an important role are described briefly in Sections 10.1 and 10.2 of this Report.

5 THE REGULATORY FRAMEWORK

Until the late 19th century, forestry legislation was aimed at protection, rather than management, and yielded poor results. Neither the Finns nor the Swedes consider the earlier efforts as true forestry laws. The first forestry law of significance was introduced in Finland in 1886 and in Sweden in 1903, only a few years before British Columbia's first significant forestry law, the *Forest Act* of 1912. Throughout the 20th century, Scandinavian forestry legislation has evolved.

- First, the law required management on a sustained yield basis and harvested areas to be reforested (no stand tending was required).
- Later, harvesting in young forests was restricted to rationale thinnings.
- Then, a requirement that consideration be given to environmental amenities was added.
Subsequently, government agencies were empowered to compel timber harvesting by way of clearcutting where stands are over-age and the productive capacity not achieved, and to force cleaning or thinning where immature stands are stagnating.

Finally, a specific law was enacted to protect certain indigenous broad-leaved trees (excluding the species used to produce primary forest products) by prohibiting, in the absence of government consent, either harvesting or replacement with another species after harvesting.

Appendix 2 contains a more detailed description of the Swedish Forestry Act.

In comparing Scandinavian forestry law to that of British Columbia, the following are some key points:

- The Scandinavian Forestry Acts apply equally to state-owned and privately owned (whether individual or company) forest land.
- The thrust of Scandinavian legislation is to use timber growing capacity fully through the entire life of a stand.
- Clearcutting is required by law in Sweden.
- Based on traditional rights there is, subject to limitations, common access to private and public land for the purpose of picking berries, flowers, and mushrooms, and for general recreation.

6 LAND USE AND ENVIRONMENT ISSUES

Forest lands in Sweden and Finland fall into three broad categories (Table 4) for the purpose of land use:

- those areas where no commercial forestry activities are permitted;
- those areas where forestry is permitted subject to certain limitations; and
- the working forest which is subject to nature conservation considerations.

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Finland</th>
<th>British Columbe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forestry not permitted</td>
<td>1%</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Forestry limited</td>
<td>4%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Working forest</td>
<td>57%</td>
<td>57%</td>
<td>29%</td>
</tr>
</tbody>
</table>

6.1 Reserve Areas

Neither Finland nor Sweden is projecting significant increases in the areas in which forestry is either prohibited or limited. Finland estimates that by the year 2000 approximately 3–4% of the country's total potential allowable annual harvest will be unavailable due to prohibitions or limitations as a result of single or multiple use of forest lands. While a similar estimate is not available for Sweden, it is reasonable to conclude that the total impact on Sweden's allowable annual harvest is less than the percentage of land area set aside and not significantly different from the Finnish projections, since some of the protected area is not forest land and some of it is forest land of low productivity.

While 57% of total land area in Sweden and Finland is working forest, only 29% of British Columbia is working forest. The smaller percentage for British Columbia is due primarily to natural factors (i.e., water, rock, and other non-productive areas). But it is also influenced by the amount of working forest society chooses to take out of commercial timber production and designate for other uses.
6.2 Management Issues

In addition to special restrictions in areas where forestry is limited, the Swedish Forestry Act provides for the issuance of regulations which address "nature conservation aspects" in the working forest, such as the size and form of clearcut areas, the establishment of new stands, the leaving of tree groupings, and the location of forest roads. Forest operators are advised that:

- trees and other vegetation on swampy and rocky land are to be saved;
- nesting trees are to be saved, and places with rare plants to be left untouched; and
- final felling areas are to be planned so as not to be too much of an eyesore in their surroundings.

The general public make heavy use of Scandinavian forests. In Sweden, 80% of urban residents walk in the forest now and then; 40% of urban residents walk in the forest more than 20 times each year; 40% of urban residents go fishing each year; over 300 000 people spend an average of nearly 30 days hunting each year; and more than 100 million litres of berries and mushrooms are picked in the Swedish forests annually. Yet, despite this heavy use, the overall day-to-day management of Scandinavian forests seems little concerned with the environmental issues so prevalent in British Columbia.

- There are virtually no old-growth forests left in Sweden.
- The protection of fresh water habitat for salt-water fish is not a widespread concern because there are only two salmon-bearing rivers left in all of Sweden and Finland, the rest no longer supporting anadromous fish populations because of dams built many years ago.
- Wildlife populations are generally on the increase, and moose and deer populations are increasing dramatically because forest management is providing good habitat for these animals.

6.3 Environmental Issues

The main environmental concerns about Scandinavian forest management appear to be, in order of priority:

- use of exotic tree species;
- preservation of mountain forests; and
- forestry operations such as peat drainage, ditching, and fertilization.

6.3.1 Exotic tree species

Scandinavians have conducted field trials on exotic species, including black spruce (*Picea mariana*), subalpine fir (*Abies lasiocarpa*), white spruce (*Picea glauca*), Siberian fir (*Abies sibirica*), Siberian larch (*Larix sibirica*), and broad-leaved species, including certain species of aspen.

Norway spruce provenances from central and eastern Europe are often used in northern Sweden, apparently without significant concern on the part of environmentalists, perhaps because the species is native to Sweden.

The Swedes began planting lodgepole pine (*Pinus contorta*) from the Yukon and northern British Columbia about 60 years ago. To date, about 400 000 hectares have been planted to lodgepole, about one-half of that by one company — SCA. By 1975, lodgepole pine made up about 25% of Sweden’s planting stock.

While lodgepole pine outperforms native species by 30 to 50% on suitable sites, and has not experienced significant difficulties in adapting to Scandinavia, some environmentalists argue against the use of any exotic species.

As a result of pressure from environmentalists, the Swedish National Board of Forestry has set planting limits on lodgepole pine of approximately 27 000 hectares per year. Within 25 years, it is estimated that lodgepole will make up not more than 10% of the planting stock in areas where it is traditionally used (primarily the northern half of Sweden).
6.3.2 Preservation of mountain forests

Strong environmental pressures in Sweden resulted in the establishment of some 50 special areas totaling approximately 600 000 hectares of virgin pine and spruce forests near mountain areas, primarily in northwestern Sweden. The stated purpose of these reserves is "to preserve large 'untouched' forests for future use." Environmental concerns do not relate to re-establishing forests after harvesting in these areas but, rather, towards assuring recreational opportunities and protecting reindeer breeding. Most of the forests in question are state owned and only about 16% of the total area set aside is productive forest. That forest area is generally low in productivity. The ultimate use of these forests is yet to be determined and timber production has not been precluded.

6.3.3 Forestry operations

A number of forestry operations — particularly drainage, ditching, and fertilization — concern the environmentalists.

Both Sweden and Finland have a comprehensive program of swamp drainage to create productive forest land in an effort to increase long-term timber production. Between 1900 and 1982, Finland drained some 5.5 million hectares of swamp, 4.7 million hectares of which were drained since 1951. The area drained in Sweden has risen to about 20 000 hectares per year, requiring in excess of 10 000 kilometres of drainage ditches. It appears, however, that partly from pressure by environmentalists and partly because of diminishing returns, the practise of drainage will subside in the future. Finland has predicted that all new drainage will be completed by the year 2000.

Ditching as a method of site preparation has been equally under criticism and now requires special permits before it is allowed. One example we saw seemed to create significant site disturbance (Figure 4).

![Figure 4](image.png)

FIGURE 4. Ditching used to prepare a site for replanting after failure following mechanical site preparation and planting. An adjacent area prepared by prescribed burning was well established.

Environmentalists have also raised concerns about the effects of fertilizer use in addition to nitrification of waterways. Special concerns have arisen because fertilization lowers the pH of soils whose quality has already deteriorated because of "acid rain." Since "acid rain" is a bigger problem in the south than in the north, regional rules have been developed permitting more fertilization in the north than the south. Fertilization treatments in Sweden have declined from an annual rate of 2% of the productive forest area down to about 1%. The rate in Finland has also declined by about 50% since the early 1970's, but, interestingly, is projected to return to that level (about 200 000 hectares per year) by the year 2000, in an effort to increase growing stock.
6.3.4 Issues of special Interest to British Columbia

Three environmental issues which have arisen in Scandinavia are of particular interest to British Columbians — clearcutting, prescribed burning, and pesticides.

Clearcutting

As noted earlier, clearcutting as the final felling is mandated by law in Sweden and extensively practised in Finland. Table 5 provides a comparison of the extent of clearcutting.

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Finland</th>
<th>British Columbia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>230 000</td>
<td>150 000</td>
<td>240 000*</td>
</tr>
<tr>
<td>% of working forest</td>
<td>1.0%</td>
<td>0.6%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

* Annual average for the 5-year period 1984/85 to 1988/89

Table 5 clearly shows that, contrary to what is often suggested in British Columbia, the amount of clearcutting in Scandinavia, expressed as a percentage of the working forest land base, is virtually identical to British Columbia.

What is different between the jurisdictions is the size of openings. In Sweden, guidelines suggest that clearcuts be limited to 20 hectares in the south and 40 hectares in the north. Many clearcuts in the south are much smaller than the suggested limit, the average size being between two to four hectares. In the north, clearcuts can be of 100 or more hectares in size, but the average is between eight to ten hectares. In Finland, the size of openings is smaller, averaging about 2 hectares. In British Columbia it is not unusual for openings to be 100 hectares, and sometimes larger, although there is a trend to smaller sizes.

While public pressure played a role in Sweden's introduction of suggested limits on clearcut sizes, the land ownership pattern also has a strong influence on the average opening size. Since 50% of the forest land in Sweden and 63% of the forest land in Finland is owned by individuals holding small parcels — an average of 45 hectares in Sweden and 35 in Finland — it is not surprising that clearcuts average much less than 100 hectares in size (Figure 5). This is in contrast to British Columbia where 94% of the forest land is public, much of it in parcels hundreds of thousands of hectares in size.

![Figure 5](image)

FIGURE 5. The land ownership pattern restricts the overall average size of clearcuts, but where land holdings are larger, so are the block openings (background).
About ten years ago, there was some controversy in Sweden about clearcutting and suggestions by environmental groups to move to selective logging. However, the argument against clearcutting failed for at least five reasons. First, the Scandinavian forests are ecologically suited to clearcutting. Abundant evidence of the destructive nature of selective logging in Sweden's timber types exists in the forests that resulted from the extensive use of that practice in the late 19th and early 20th centuries. It was that hard-learned experience which moved the Swedes to mandate clearcutting by law. Second, because of the relatively small size of openings, one may stand in a clearcut and see adjacent areas which were clearcut earlier and now support vibrant new growth (Figure 6). Third, because clearcutting has been extensively practised for some 75 years and because intensive forestry has been ongoing for almost 50 years, there are many examples of clearcutting working through successive rotations. Fourth, because the forests harvested in Scandinavia are generally very young and vibrant, most of the wood felled is used, leaving very clean harvesting sites with little logging residue. Aesthetically, this is much more pleasing than logging in overmature and decadent forests which often results in at least some unusable residue left on the ground. Fifth, as noted in Section 6.2, the general public in Scandinavia spend time in the woods. This permits them to observe first hand the successes of clearcutting and regeneration practices, so they are not as easily influenced by external sources as is the more urbanite British Columbian.

\[
\text{FIGURE 6. Newly established forests can easily be seen from most clearcuts.}
\]

**Prescribed burning**

From being common practice in northern regions, very little prescribed burning is now used in either Sweden or Finland, primarily because of land ownership patterns and expense, but also because of objections from forest workers. Small land holdings increase the chance of escape into another owner's timber, making fire liability a major issue. Overall, the Swedish attitude toward prescribed burning seems more negative than that of the Finns. On many sites, Scandinavians have found that prescribed burning has outperformed mechanical site preparation techniques both in regeneration and in maintaining site productivity. For these reasons, Scandinavians are considering an increase in burning, especially in the northern regions.

**Pesticides**

Although there are few limits on the use of pesticides for domestic or agricultural uses, there are severe limits on the use of herbicides, insecticides, and fungicides in forestry.
In Sweden, limitations have been in effect for many years and the use of herbicides in commercial forestry will be completely banned as of 1990. Most Swedish forest managers moved to other treatments long before the deadline. MoDo, for example, voluntarily stopped the use of herbicides in 1971. In Finland, aerial spraying of herbicides is completely banned. Ground applications are still permitted but require a permit from the local community, which is rarely granted. These constraints appear to have been imposed primarily for social reasons, rather than as a result of scientific studies demonstrating negative environmental impacts.

The loss of herbicides is not as serious in Scandinavia as it would be in British Columbia. There is not as much brush in young forests in Scandinavia as there is in British Columbia and the brush is mainly woody and can be cut, unlike the herbaceous material which is a problem in British Columbia.

To minimize their brush problems, Scandinavians clearcut, site prepare and plant quickly, and plant in high densities. Where these techniques fail to control the brush, they employ primarily motor manual saws at higher costs than herbicide applications. Work is ongoing to develop brushing machines to reduce costs. Some are now in production.

7 SILVICULTURE

Scandinavian silviculture is both advanced and simple. It is advanced in that it is a total system over the rotation. All phases are coordinated to provide treatments that meet predetermined targets in volume and quality. It is simple in that forest ecosystems do not have the complexities of British Columbia’s forests. They have only three native commercial species: Scots pine (Pinus sylvestris), Norway spruce (Picea abies), and birches (Betula species). The topography is fairly flat and the soils mainly coarse textured. The silvicultural systems used are similar to those used in the central interior of British Columbia; however, they are done as a total regime over a rotation, not as individual stand treatments. Treatments have proven to be very successful. New forests are exceeding earlier predictions in both quantity and quality.

Rotation periods in Scandinavia are generally 70 to 110 years in the south and 80 to 140 years in the north. The average mean annual increment (mai) is about 3.5 m³/ha/year, but intensive management is expected to increase that average to 5 or 6 m³/year, with maximum mai anticipated to be 12 to 15 m³/ha on the best sites. Annual increment is higher in the south (5.3 m³/ha/year) than in the north (2.0 m³/ha/year). At the time of harvest, southern crops average 30 m in height and 30 cm in dbh on good sites while northern crops average 15 m in height and 20 cm in dbh.

Clearcutting is the predominant harvesting method. Some private owners, wishing to save the expense of planting, rely on seed trees taken in a final clearcut felling after a new crop is established through natural regeneration (Figure 7). Even in this approach, clearcutting and not selective logging is the silviculture system of choice.

A forest owner must submit a plan, indicating how the forest will be harvested and regenerated, to the local County Forest Board at least 30 days before harvesting is to commence on areas exceeding 0.5 ha. If the Board does not comment on the plan within the 30 days, the forest owner may proceed with his plan. These plans give the County Forest Boards, in consultation with the County Environment Authority, an opportunity to consider whether the proposed cutting should be forbidden or modified for environmental reasons.

Much current Scandinavian silviculture has developed to address poor past practises and present day reluctance of many private owners to manage their lands for timber production. By the 1930’s many Scandinavian forests were severely depleted. There was an enormous amount of backlog not satisfactorily restocked (NSR) land and also a shortage of middle-aged stands. At the end of the 1930’s, for example SCA, one of Sweden’s largest land owners, found that two-thirds of its forest land was backlog NSR.
A four-part strategy was adopted to address the resulting poor age-class distribution.

- The poorest quality stands on the best sites were harvested first to bring them back to vibrant production as soon as possible.
- Fertilizing in older stands was accelerated to increase growth rates.
- Fast-growing new stands were established using *Pinus contorta*.
- Longer rotation periods were introduced in areas where young stands had been harvested too early.

This program is generally viewed as having worked beyond expectations. Concerns about the lack of middle-aged stands, which remained high just ten years ago, now seem to be subsiding.

Extensive thinning operations have also been adopted to address wood supply shortages. These shortages have two primary causes. The first is the age-class structure problems referred to above. Thinning does not rectify this problem, but it provides a much-needed wood supply while it is being addressed. The second cause is the removal of privately held forest land from active timber production. These removals are attributed to a tax structure which discourages harvesting and to the inheritance of such land by urban dwellers who have little interest in forest management and are not reliant on the forest for income.

### 7.1 Tree Improvement

The Swedish tree improvement program is coordinated under the Institute for Forest Improvement (the "IFI"), an independent organization separate from government, industry, and the private land owners. The organization works cooperatively to provide research direction to the tree improvement program. Individual companies or the government maintain seed orchards.

Established by forest owners in 1936 as an association for forest tree breeding, this group initially produced tree seedlings for forest plantations. In the 1950’s, it shifted its focus to establishing and managing seed orchards. By 1967, it had evolved into the Institute for Forest Improvement, responsible for:

- breeding of forest trees in Sweden; and
- research and development work on tree breeding and forest fertilization.

The activities of the Institute are jointly funded (50/50) by the Swedish state and the forest land owners. Operating under the guidance of a Board, with equal representation between state and forest owners, the Institute undertakes both directed and service work on breeding and mass propagation.
The Board of the Institute works within a continuous 10-year program, the first 3 years of which have secured funding. Program funding for tree improvement is about Cdn. $4 million per year, split by species as follows:

<table>
<thead>
<tr>
<th>Species</th>
<th>Cdn. $ million/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scots pine</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>0.2 – 0.4</td>
</tr>
<tr>
<td>Birch</td>
<td>0.1</td>
</tr>
<tr>
<td>Hybrid aspen</td>
<td>0.03</td>
</tr>
</tbody>
</table>

The Institute maintains a staff of about 80 people, which include 12 tree breeders for four species of concern (Scots pine, lodgepole pine, Norway spruce, and birch). The Institute does breeding research and progeny testing, locates seed orchards, performs grafting, and provides advice on tree improvement. Genetic evaluation of progeny and creation of new breeding generations are important parts of the Institute’s work.

The Institute itself owns no seed orchards but assists the seed orchard owner (which may be a single company or group of companies) with selection and grafting of suitable progeny and provides extension and research support for the management of seed orchards. Third-generation orchards have been started in some species. Lodgepole pine is well established in seed orchards. SCA have five such orchards and expect to start a second-generation orchard in the near future (Figure 8).

FIGURE 8. One of SCA’s five lodgepole pine seed orchards.

The general aim of the breeding program is to improve timber quality, increase volume (genetic gain is estimated at 15–25% over the rotation) and improve frost hardiness. The latter is a serious problem affecting seedling growth in the northern areas of Sweden and frost sensitive low-lying areas in south Sweden.

The British Columbia Interior Tree Improvement Program is similar to Sweden’s in that it is directed to a limited number of species. However, whereas the Swedish IFI has 12 breeders, the British Columbia Interior has only three — one for each interior species.

As British Columbia companies become more conversant with tree improvement programs, it may be prudent for the British Columbia Tree Improvement Councils to consider moving to the Swedish Institute model, whereby companies contribute financially to the research aspect of tree improvement. There are two advantages. First, longer term financial planning may be possible. Second, companies will have a greater vested interest in research into tree improvement and will want to be assured that the work of the tree breeders is directed in areas of importance to them.
7.2 Regeneration

7.2.1 Artificial vs. natural regeneration

About 90% of harvested areas in Sweden are regenerated by planting or sowing, the latter being a very small program. In Finland, 50% of the harvested areas are regenerated by planting or sowing (30% planting; 20% sowing) and 50% by natural regeneration. By comparison, it is estimated that planting comprises about 60% of British Columbia's regeneration program. Most of the natural regeneration in Sweden is carried out by private land owners who accept longer regeneration delays in return for lower regeneration costs and, to a lesser extent, a feeling that they are following a more natural management regime.

In Finland, the split between planting and natural regeneration seems to follow site quality closely. Good and medium sites are planted and poorer quality sites are left to regenerate naturally. Finns also report that there is pressure to move to more natural regeneration because of the high cost of planting, the lack of a silviculture workforce, and, to a lesser extent, concerns among environmentalists about planting leading to monoculture. They are also predicting a slight shift by the year 2000 from planting to sowing. Swedes are also looking at increasing natural regeneration in mid- and southern Sweden to about 25%, but they are also expecting a decrease in reliance on natural regeneration in the higher latitudes and higher elevations. Overall, the reliance on natural regeneration for Sweden is not expected to change. Natural regeneration is generally used only in Scots pine, but some successful natural regeneration is also experienced in spruce. Where natural regeneration is relied on, about 75–125 seed trees per hectare are left on the clearcut area.

For Sweden as a whole, the species breakdown for planting is: 46% Scots pine; 36% Norway spruce; 17% lodgepole pine; and 1% deciduous. There are dramatic local variations from these coniferous averages, depending on site conditions and on the responsible manager's faith in lodgepole pine.

Whether regeneration is by planting, sowing, or seed trees the maximum regeneration delay in Sweden is typically three years.

7.2.2 Nursery management

The Swedes plant about 500 million seedlings per year; the Finns about 200 million. This demand requires a substantial nursery program. In Sweden, about 75–80% of seedlings are container grown, whereas in Finland only 60% are container grown. There are about six container systems on the market. Finns reportedly prefer peat or paper pots, but we observed extensive use of plastic containers at company nurseries operated by MoDo and SCA in Sweden (Figure 9).

The SCA nursery — the Boggrundet Tree Nursery — is the largest in the world, producing some 75 million seedlings per year from 400 kilograms of seed. The sowing process is highly automated. Each plastic seedling container tray holds 67 pots; each container one seed. The nursery can sow up to one million seeds per day. After sowing, the containers are placed in metal frames, holding 60 trays apiece, and are handled in those frames from the sowing shed through all growing and transportation processes until they are ultimately delivered to planters in the field. The frames, holding the containers and the seedlings, are transported to the field in trucks each capable of carrying 300 000 seedlings. The trucks return the empty containers in the frames from the bush to the nursery (Figure 10).

The Boggrundet nursery is able to produce 75 million seedlings a year by force-growing four crops from March to August each year. The first crop is planted that year, and the other three the following year, after over-wintering in open-air beds (Figure 11).

While Scandinavian nurseries are more automated than those in British Columbia, seedling quality is not graded and, overall, the quality of stock appeared to be less than that of British Columbia stock. Scandinavians seem to compensate for lower stock quality through good site preparation, planting more seedlings per hectare, and intensive stand tending after planting.
FIGURE 9. A MoDo greenhouse showing plastic containers in metal frames.

FIGURE 10. At SCA’s Bogrundet Tree Nursery, empty frames from the field are removed from the transport truck and full frames are loaded for delivery to the planting sites.

FIGURE 11. Stock is overwintered in open-air beds and may be sprayed to ward off the pine weevil which attacks plantations.

7.2.3 Site preparation

Site preparation is necessary to prepare plantable spots, warm the soil, and reduce losses from the pine weevil (Hylobiidae sp.). The weevil is present in duff and will girdle new seedlings. Exposing mineral soil around the seedling discourages the weevil from leaving the duff. As in northern British Columbia, cold soil temperature is often a limiting factor to growth, and exposing the soil and rock raises the temperature and enhances early growth (Figure 12). Because harvested stands are relatively young and not generally subject to waste, decay, or breakage, there is little debris left after logging to impede planters, but plantable spots can be increased through site preparation on sites which are particularly wet or rocky.

Site preparation is usually done the year after harvesting, although there appears to be a trend to speed the regeneration process by preparing sites immediately after harvesting.
FIGURE 12. A rocky site prepared mechanically.

Swedes report that about 90% of clearcut areas are treated by mechanical means, mainly disc trenching, mounding, and plowing. Of these methods, disc trenching is the most popular, accounting for about 65% of the treated area for all of Finland and about 85% in southern Finland. Plowing has raised environmental concerns but is still quite common in northern Finland where, unlike Sweden, an environmental permit is not required. As in British Columbia, mounding is popular on wet sites, accounting for about 25% of all mechanical treatments in Sweden, and is expected to gain in popularity, but costs about 25% more than disc trenching. Figures 13 and 14 show a new type of mounder, recently made available for use in British Columbia. Little prescribed burning is done, although some foresters think it would be better for some sites than mechanical methods, and we saw evidence to that effect. Many sites are very rocky and could be difficult for equipment. Depending on terrain and equipment, productivity in mechanical site preparation ranges between 0.5 and 1.0 hectares per hour.

7.2.4 Planting

Harvested areas are generally planted the year after the site is prepared, although there is a trend to reduce the regeneration delay by planting in the same year as site preparation.

In Sweden, the Forest Law requires in most cases that at least 2100 seedlings be planted per hectare. General practice is to plant between 2200 and 2400 per hectare, and in some cases even more. In Finland, the average is slightly lower at about 2000 seedlings per hectare, but still substantially above the British Columbia average of 1200 seedlings per hectare in the Interior and 800 seedlings per hectare on the Coast. High densities are employed as protection against browse problems, relatively high seedling mortality, and the possibility of future diseases. The higher densities also assist natural pruning and increase wood density (both popular with a solid wood industry seeking high-value products) and provide stems for thinning, which creates a much-needed wood flow over a significant period in the life of the stand.

Swedes aim for some 2200 surviving seedlings per hectare after two years. Survival rates in the south are about 90 to 95%, but in the north considerably less. Bareroot plantations were reported by one company to be twice as likely to fail as container plantations.

Planting productivity varies depending on the planting system, the planting conditions, and the method of payment. Finns reported that, under similar conditions, bareroot planting with a mattock averaged 600 seedlings per day, whereas tube planting averaged 1000 seedlings per day. On easier terrain in the south, productivity can rise to 2200 seedlings per day compared to 1300 to 1600 in the central areas. A similar contrast exists when a piece rate is used (average 2200 seedlings/day) compared to an hourly rate (average 1300 to 1600 seedlings/day).

Where the plastic container system is used, the planter straps two containers at a time to his or her belt (67 seedlings in each container) and plants one container while walking away from a central storage site and one while returning to the storage area to pick up another two containers (Figure 15). Container-grown seedlings are planted with a tube.

Attempts to mechanize planting have been ongoing for 20 years but are yet to be successful. The most successful prototypes have averaged 1400 seedlings per production hour, but are considered only partially practical.
7.3 Stand Tending

Stand tending in Scandinavia is divided into three important categories: cleaning or pre-commercial thinning; thinning; and fertilization.

7.3.1 Cleaning

In Sweden, the Forest Law has required since 1979 that young stands be cleaned before they reach a height of 3 metres, and the general practise is to do so when trees reach 1.5 to 2 metres. Between 80 and 90% of the 450 000 hectares which the Swedes estimate should be cleaned each year are treated. In 1986, the Finns cleaned almost 260 000 hectares and are aiming for 335 000 hectares per year by the year 2000.

Herbicides are generally not available for cleaning. Hand cleaning with a brush saw is the dominant method, with productivity averaging about 0.1 hectare per hour (Figure 16). Apart from the new mounder, the only new silviculture equipment of potential interest for British Columbia is that used for cleaning. There have been rapid advancements in mechanized cleaning in Scandinavia since 1985. In 1988, about 1% of cleaning was done by machine in Sweden, but this is expected to rise to 10% by the mid-1990's. The Swedish experience indicates that cleaning machines are economically competitive in stands where more than 10 000 stems per hectare are to be removed (Figure 17, 18). Productivity for these machines is about 0.2 to 0.3 hectares per hour.

On more productive sites it may be necessary to do up to three cleanings. However, hardwood competition often is not completely eliminated at the cleaning stage. First, frost damage is a significant problem in Scandinavia, and the presence of hardwoods can eliminate frost pockets and reduce damage to conifers. Second, moose and deer browse is also a major problem, and leaving deciduous trees provides an alternate food source during the part of the year when deciduous trees are in leaf. Third, some deciduous species (birch in particular) are commercially valuable and can be utilized from a thinning. As a result, it is not unusual to leave 1500 birch stems per hectare after cleaning, most of which will come out in the first thinning.
FIGURE 16. Hand cleaning, or pre-commercial thinning, with a brush saw is the dominant method used in Sweden.

FIGURE 17. Cleaning machines have been shown to be economically competitive in stands where more than 10,000 stems per hectare were to be removed.

FIGURE 18. Close-up view of cleaning machine's cutting tool.
7.3.2 Thinning

Subsequent to the cleaning mandated by law, thinnings are rationalized on the basis of growth and yield, the cost of wood, and wood supply needs. Up to three commercial thinnings may take place during a rotation, although the optimum number is not widely agreed upon. Thinning is widely practised and contributes 25% of the annual volume harvested in both Sweden and Finland. About 150 000 hectares in Finland and some 225 000 hectares in Sweden are thinned each year. The importance of thinning is expected to increase over time as large areas of young stands reach thinning age. In Finland, thinning is expected to increase by 70% between 1986 and the year 2000. Growth and yield seem to be well understood, and that understanding is translated into detailed thinning schedules identifying size, density, and quality limits.

A typical thinning regime might begin with a first thinning at age 30 to 40 years when the trees would be about 10 metres high and have a density of about 1600 to 2000 stems per hectare. This thinning would reduce the density to about 1000 stems per hectare, recover 60 m$^3$ per hectare, and produce about 10% sawlogs by piece count. A second thinning might occur at age 55 to 60 years, leave about 500 stems per hectare, recover 80 m$^3$ per hectare, and produce nearly 20% sawlogs by piece count (Figure 19). The final felling would take place at age 95 to 100 years, recover about 350 m$^3$ per hectare, for a total volume recovery over the harvest sequence of about 500 m$^3$ per hectare.

Both motor manual (chainsaws) and mechanized methods are used for thinning, although mechanization appeared more common in Sweden (Figure 20). In either case, operators are well trained and little, if any, damage is rendered to the residual stand in the thinning process. In fact, branches from the thinnings are put down ahead of the machines to reduce soil compaction (Figure 21).

![Figure 19. Pulp logs taken from a thinning operation.](image-url)