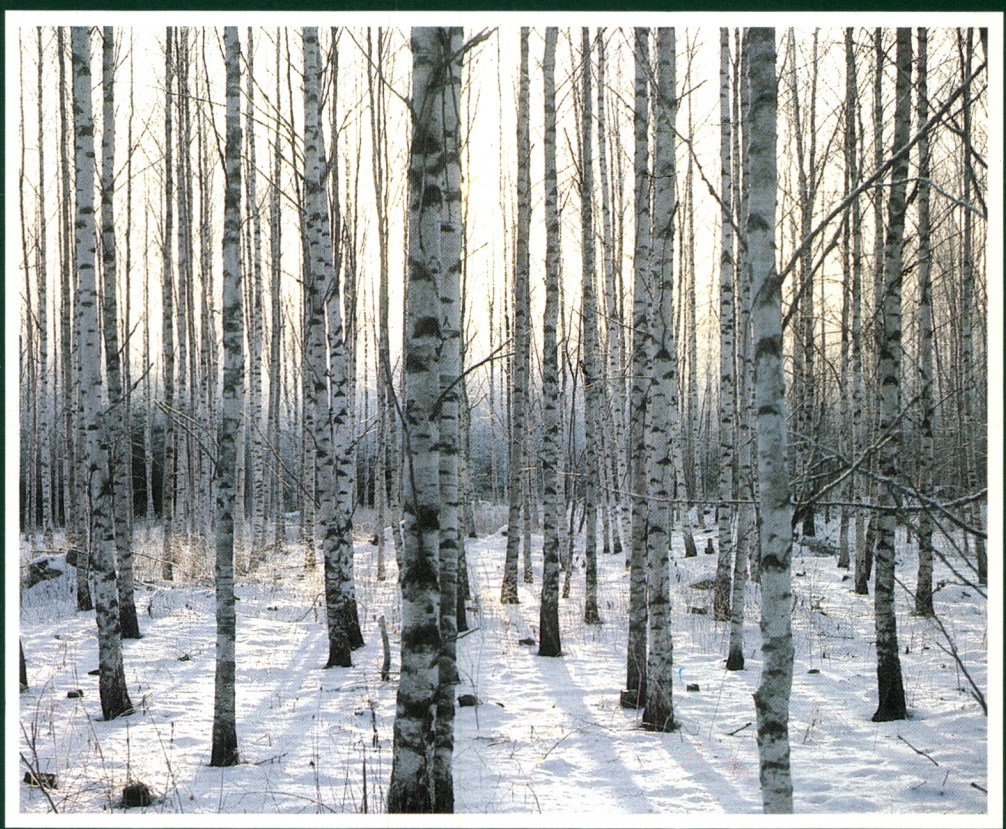
METSÄNTUTKIMUSLAITOKSEN
TIEDONANTOJA 175

METSÄTEKNOLOGIAN TUTKIMUSOSASTO



PENTTI HAKKILA AND OLLI UUSVAARA

# DEPARTMENT OF FOREST TECHNOLOGY

## AT THE FINNISH FOREST RESEARCH INSTITUTE

HELSINKI 1985

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CONTENTS




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# 1 THE FINNISH FOREST RESEARCH INSTITUTE

Finland, which is located between the 60th and 70th parallels of northern latitude, is poor in natural resources. The country has no indigenous oil, coal or natural gas reserves. The harsh climate is not too favourable for agriculture.

Nevertheless, 19,7 mill. hectares or 65 % of Finland´s land area consists of productive forest land. The annual growth of timber is roughly 67 million $m^3$ including bark. For a population of 4,8 million people the available cut, 65 mill. $m^3/a$, is more per capita than in any other country.

Consequently, the relatively high standard of living in Finland is to a large extent based on intensive utilization of the renewable forest resources. Efficient management of the forests and dynamic forest industries are vital for the national economy of the country. For example, forest and forest industry products account for about 40 % of export incomes.

In the southern half of Finland the allowable (4,6 $m^3/ha/a$) and actual (3,5 - 4,0 $m^3/ha/a$) drain is higher than anywhere else in corresponding climatic conditions. Despite the intensity of the wood utilization the total volume of the growing stock, 1,6 bill. $m^3$, is increasing. The favourable development had hardly been possible without the basic and applied forest research carried out in Finland during the past 70 years.

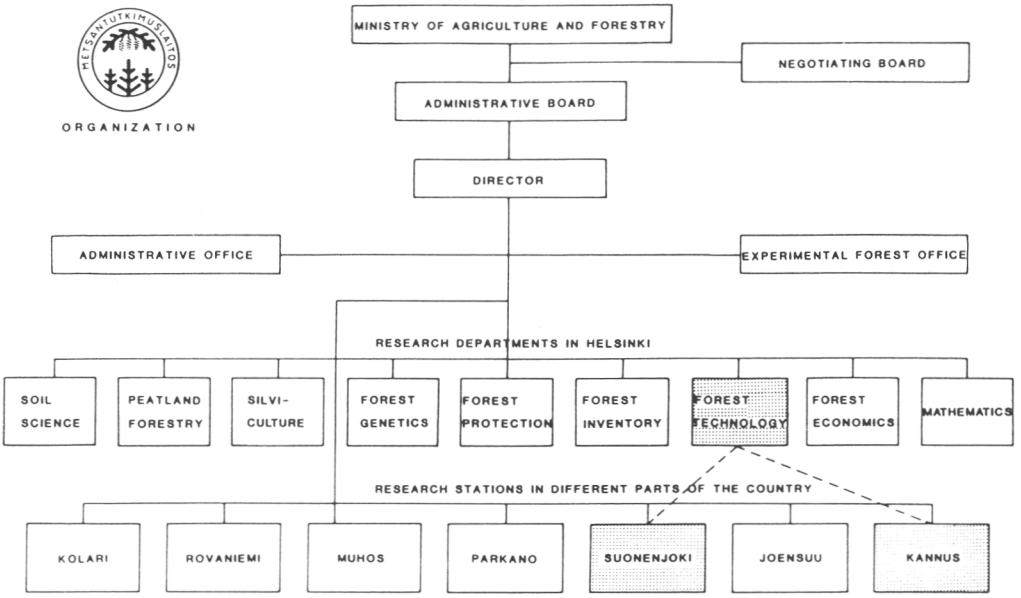


Figure 1. Organization of the Finnish Forest Research Institute.

The Finnish Forest Research Institute was established in October, 1917 only a few weeks prior to Finland's Declaration of Independence. The Institute is subordinated directly to the Ministry of Agriculture and Forestry. It is headed by an Administrative Board appointed by the Government. A Negotiating Board acts as a link between the Institute and the practical forestry. Professor Aarne Nyyssönen has been the Director of the Institute since 1984.

The actual research work is carried out in the research departments (Figure 1) in Helsinki as well as at 7 research stations and 3 experimental stations (Figure 2) in different parts of the country. In the beginning the Institute consisted of three small departments each headed by a

professor. Today there are 9 departments and 13 professors.

The Institute employs approximately 600 permanent employees, including some 160 research officers. The staff, including the professors, has no teaching obligations. The annual budget for 1985 was 83 million Finnmarks (U.S. $ 13 mill.).

The Institute has a unique network of experimental forests in nearly all geographic and climatic regions of Finland covering a total area of 79 000 hectares. In addition, it controls 62 000 hectares of nature conservation areas.

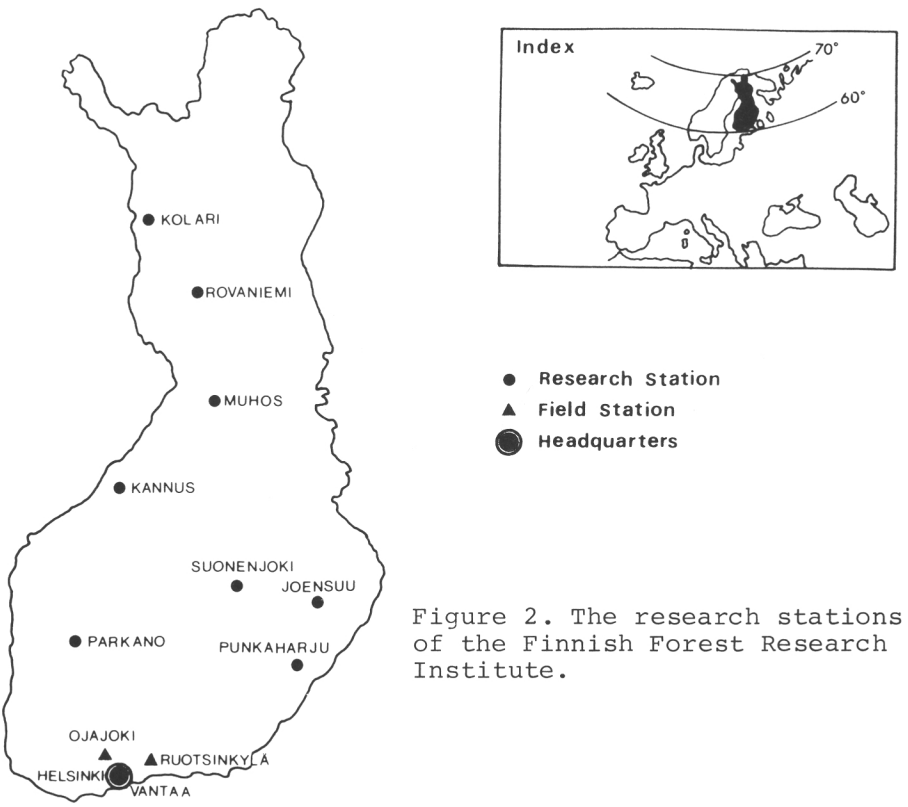


Figure 2. The research stations of the Finnish Forest Research Institute.

The experimental forests offer excellent opportunities for long-term field experiments and permanent sample plots. For practical reasons, however, studies on logging operations and wood utilization are in most cases carried out outside the Institute forests in cooperation with the forest industry, The National Board of Forestry, machine manufacturers and other parties.

The research results are published in three series of the Institute:

- "Communicationes Instituti Forestalis Fenniae" is intended mainly for scientists and is published primarily in English.
- "Folia Forestalia" is more practical in nature. The language is generally Finnish but the reports always include a short summary in English or some other foreign language.
- "Metsäntutkimuslaitoksen tiedonantoja" is usually printed in Finnish and contains preliminary reports on ongoing studies, miscellaneous publications like the present one and so forth.

# 2 THE DEPARTMENT OF FOREST TECHNOLOGY

## Research fields

The Department of Forest Technology was established in 1931. Because of limited resources and the close links between forest work science and wood utilization 50 years ago, these two scientific fields were combined into a single professorship.

The research problems gradually became more complicated. Both spheres started to require thorough specialization and it finally became necessary to divide the field into two sections. Since April, 1972, the Department has had two professorships: Forest Operations and Wood Utilization. The following scientists have been either permanent or acting professors of the Department.

| | |
|---|---|
| **Professors of Forest Technology:** | |
| Olli Heikinheimo | 1931-1934 |
| V.T. Aaltonen | 1934-1938 |
| Ilmari Vuoristo | 1938-1939 |
| N.A. Osara | 1939-1941 |
| V.T. Aaltonen | 1941-1944 |
| Matti Jalava | 1944-1948 |
| Paavo Aro | 1948-1967 |
| Veijo Heiskanen | 1967-1970 |
| Pentti Hakkila | 1970 |
| Veijo Heiskanen | 1971-1972 |
| **Professors of Forest Operations:** | |
| Pentti Hakkila | 1972-1976 |
| Matti Kärkkäinen | 1976 |
| Pertti Harstela | 1977-1979 |
| Pentti Hakkila | 1979- |
| **Professors of Wood Utilization:** | |
| Veijo Heiskanen | 1972 |
| Olli Makkonen | 1972 |
| Veijo Heiskanen | 1973-1976 |
| Matti Kärkkäinen | 1977-1979 |
| Pentti Nisula | 1980 |

| | |
|---|---|
| Matti Kärkkäinen | 1981-1982 |
| Pentti Nisula | 1983 |
| Olli Uusvaara | 1983- |

The scientific sphere of the Department of Forest Technology covers by decree forest work, its development and mechanization, ergonomics and wage scales (Forest Operations) as well as the structure and properties of wood, the raw material of forest industries and the scaling of timber (Wood Utilization). The two Sections are divided into major problem areas as follows:

Forest Operations Section

1. Harvesting and transport operations
2. Silvicultural operations
3. Ergonomics of forest work

Wood Utilization Section

4. Structure and properties of wood
5. Wood utilization
6. Scaling of timber

The main targets of the studies of the Forest Operations Section are to rationalize forest operations by increasing the productivity of forest work, decreasing work costs, developing the methods and machines ergonomically, intensifying the recovery of forest biomass, improving the quality of work results, decreasing the damage done to standing trees and forest soil in logging operations and developing ecologically sound operation systems. The programme is aimed to serve all parties of forestry and the forest industries and the forest machine manufacturers, as well as to bring about the realization of the Finnish energy

policy programme. The studies are often closely connected with machine and method development.

The tasks of the Wood Utilization Section are to study the technical properties of different tree species and timber assortments, the effects of environmental factors and stand conditions on wood properties, the seasoning of timber and the suitability of wood for various purposes in the forest industries. Moreover, the Section studies and develops the scaling of timber and produces conversion factors for scaling.

## Location

The nine research departments of the Finnish Forest Research Institute are located in Helsinki. Because of a shortage of office space they are presently situated in three different locations. The Department of Forest Technology is in the Forest House which lies in the centre of the city. The address is Unioninkatu 40 A, 00170 Helsinki. The Department of Logging and Utilization of Forest Products at the University of Helsinki is also located in the same building.

A part of the research activities of the Institute are decentralized to research stations. All research work, however, regardless of the location is subordinated to the research departments.

In addition to its headquarters in Helsinki, the Department of Forest Technology has a centre for forest operations research at Suonenjoki Research Station (9 persons) in central Finland since 1974. In long-term planning, the Department intends to concentrate the activities of both Sections also to a new research station to be completed in 1985 in the western coastal area at Kannus. As a matter of fact, the first forest operations specialist moved to Kannus already in 1982.

## Equipment for forest operations research

Modern work studies require diverse equipment for the automatic recording and data processing of work results, time consumption, ergonomic variables, machine performance, etc. In the ergonomic studies especially, development of new instruments has been a necessary precondition for the expansion of the research sphere. Consequently, despite financial limitations, great efforts are being extended to improving measuring technique. The most important equipment is briefly presented below.

Measuring work conditons is an essential aspect of ergonomic studies. For this purpose the Department has equipment for measuring noise and vibration. Considerable efforts are directed to studying the effects of low frequency whole body vibration. A portable dust sampling kit is used in studies concerning the production and handling of wood chips, the spreading of wood ash to nature

and so forth. For recording the work pace, monotony and other factors of forest work, the Department has a portable keyboard connected to a microcomputer. The same system is used for conventional time studies, too.

Another essential aspect in the ergonomic studies is fatigue of the worker. For bioelectrical studies (e.g. EKG and EMG) the Department has a telemetric measuring system where signals are transmitted to a tape recorder or to a microcomputer. The data are analyzed with a desk computer, or the signals are transmitted directly to the computer in laboratory studies. The effects of mechanization and automation on the worker are of great interest as well.

A forest machine simulator with manipulators of the actual size and a crane and processing device of 1/8 size has been developed at the Suonenjoki Research Station. The device is used to study different machine elements and work methods or ergonomical variables in controlled conditions. It could also be used to train forest machine operators.

Some forest operations, especially in connection with delivery sales, are carried out by farmers and small-contractors with farm tractors equipped with auxiliaries which are often powered through the take-off shaft of the tractor. A torsion and rotational speed transducer can be connected with the take-off shaft to study power consumption and peak torsions of small chippers or other farm tractor driven equipment.

One of the targets of the fuelwood studies is the improvement of the fuel value of wood through seasoning. A portable electronic scaling system with a capacity of up to 6 tons is used to observe weight changes of 15 $m^3$ chip containers in field conditions.

Equipment for wood research

In addition to standard laboratory equipment like ovens and scales, special equipment has been developed for measuring wood characteristics such as fibre length and ring width and for wood densitometry.

Ring width measurement has been further developed by changing the traditional electro-mechanic measuring device into an electronic one and by hooking a microcomputer to the system. The microcomputer handles data collection, controls data accuracy, calculates intermediate results and transfers data to the Institute's VAX 11/780 computer.

Wood densitometry is a technique for assessing ring width and basic density characteristics of small wood samples for anatomical, physiological and technological studies of wood. The equipment for densitometric studies at the Department is composed of the following units: sample preparation by sawing and extraction, equipment for sending soft x-rays through the wood samples, equipment for developing x-ray films and a microdensitometer for interpreting x-ray films. Microcomputer-based interface equipment is being developed for automatic collection and

transfer of data to the main computer. In addition, a computer-based Wood Radiation Densitometry Bibliography system has been developed.

## Personnel in 1985

As of February, 1985 the Department has 40 permanent employees including those working at the Suonenjoki and Kannus Research Stations. The special fields of the staff members are presented below.

Forest Operations Section:

Research officers:

Appelroth, Sven-Eric. D.F. Research Specialist (reforestation operations)
Eeronheimo, Olli. M.F. Research Officer (logging operations)
Hakkila, Pentti. D.F, Professor (utilization of residual wood, thinning operations)
Harstela, Pertti. D.F. Director of the Suonenjoki Research Station (ergonomics, thinning operations, nursery operations)
Heikka, Timo. M.F. Research Officer (logging operations)
Juntunen, Marja-Liisa. M.Sc. Research Officer (ergonomics, work organization) at Suonenjoki
Kanninen, Kaija. M.Sc. Research Officer (work psychology, work safety)
Maukonen, Antti. M.F. Research Officer (logging operations) at Suonenjoki
Mäkinen, Pekka. M.F. Research Officer (ergonomics and logging operations) at Suonenjoki
Nurmi, Juha. B.F. Research Officer (fuel chips)
Piirainen, Kimmo. M.sc. (Eng.) Research Officer (design and construction of research instruments)
Sirén, Matti. M.F. Research Officer (thinning operations)

Other permanent research personnel:

Aaltio, Hannu. Data Processing Specialist
Harstela, Antero. Machine Technician at Suonenjoki

Kalaja, Hannu. Forest Technician (harvesting of forest chips)
Kautto, Kari. Foreman at Suonenjoki
Kirjavainen, Tiina. Typist, laboratory assistant
Kuikka, Martti. Machine Technician at Suonenjoki
Nevalainen, Tapio. Foreman
Paananen, Urpo. Research Assistant at Suonenjoki
Salo, Erkki. Foreman
Salo, Veikko. Field Assistant
Siekkinen, Raija. Secretary
Takalo, Sauli. Foreman (handtools and light machines) at Kannus
Tervo, Leo. Forest Technician (nursery operations, logging) at Suonenjoki

Wood Utilization Section

Research Officers:

Löyttyniemi, Kari. D.F. Research Specialist (wood defects, seasoning)
Rikkonen, Pentti. M.F. Research Officer (timber scaling)
Sairanen, Pentti. M.F. Research Officer (timber scaling)
Salmi, Juhani. M.F. Research Officer (timber scaling, tree species identification)
Sauvala, Kari. Research Technician (wood densitometry, design and construction of instruments)
Tuimala, Aili. M.F. Research Officer (wood properties)
Uusvaara, Olli. D.F, Professor, Department Chairman (wood quality and utilization)
Verkasalo, Erkki. M.F. Research Officer (energy chips)
Voipio, Raili. B.Sc. Assisting Research Officer

Other permanent research personnel:

Järvinen, Tapio. Research assistant
Kinanen, Pirkko. Secretary
Klemetti, Kaarina. Laboratory assistant
Lehtimäki, Jukka. Field Assistant
Muronranta, Leena. Drawer
Oittinen, Tauno. Forest Technician (timber scaling)
Rytkönen, Aune. Typist
Salo, Veijo. Field Assistant

# 3 BACKGROUND OF THE RESEARCH ON FOREST TECHNOLOGY

To understand forest technology research in Finland, the foreign reader ought to know the general background and conditions of timber harvesting and utilization. Some of the most important factors influencing the selection of work methods as well as research and development themes are mentioned in the following.

- Finland's forest resources have increased gradually since the 1920s, when they were inventoried for the first time. The volume of spruce and pine saw timber trees especially has increased by 43 % and 12 % respectively since 1952. Pine is more valuable and is preferred as saw timber. Due to improved growth rate the sawmill industry is somewhat concerned about the quality development of pine saw timber.

- The selection of tree species is exceptionally small: roughly 44 % of the growing stock is Scots pine (Pinus silvestris), 38 % Norway spruce (Picea abies), 15 % birch (Betula verrucosa and B. pubescens) and 3 % other hardwoods (mainly Alnus incana and Populus tremula). The scarcity of tree species is an obvious advantage from the management, silvicultural, transport, storage and utilization points of view.

- A major part of the timber harvested from the final fellings is presently derived from stands which were naturally regenerated towards the end of the 19th century. These stands have been thinned repeatedly,

and consequently the proportion of defective timber is very low. The target rotation period is 70 - 90 years in southern Finland and 100 - 120 years in northern Finland. One precommercial thinning and 2 - 3 commercial thinnings are generally carried out during the rotation period.

- Stands at the seedling or pole stages account for about 3,7 million ha, or 19 % of the total area of productive forests. Two thirds of these young stands have been regenerated naturally and one third artificially. If the current rate of artificial forest regeneration, 130 000 ha/a out of the total regeneration area of 200 000 ha/a, is maintained, man-made forests will account for 30 % of the total forest area of Finland by the turn of the century. Because of the age class distribution of the forests, the need for early thinnings of young stands will increase considerably from the present level during the 1990s.

- The forests generally lie below the altitude of 200 m. The terrain is characterized by low hills. Forest operations are never carried out in real mountain conditions. Cable logging systems, for example, are not needed.

- The prevailing forest soil type is moraine, often featured by an abundance of stones. On the other hand, a thick peat layer is common on flat bogs, which account for one third of Finland's land area. At present, the transport of timber from drained and

undrained bogs has to be restricted mainly to the winter season. During the winter months the ground generally freezes, thus facilititating the haulage of timber from the forest. This does not, however, happen each year. The thickness of the snow cover may increase to a height of one metre.

- Repeated selective thinnings in order to concentrate the production capacity of the site into an optimum number of stems are an essential part of Finnish forest management. At present, roughly one fourth of the timber is harvested from thinnings. To avoid damage to standing trees during the thinning process, and because of both the small average volume of the trees and the shortage of satisfactory landing sites in private wood lots, the shortwood method combined with load carrying forest tractors (forwarders) is the prevailing system in logging. Pulpwood is cut into 2 - 6 m and sawlogs into 3 - 7 m lengths at the stump before haulage to the landing site.

- About 75 % of timber comes from private forests. The average area of a private forest holding is only 32 ha. The average sale from a private forest is about 300 $m^3$ of timber. The small volume of timber sales increase logging costs and constrain mechanization.

- The state effectively promotes the construction of forest roads so that the average hauling distance to the truck road is some 350 - 400 m. There is a stock of 2300 forwarders designed especially for Nordic

terrain conditions. In addition, there are about 250,000 farm tractors in the country.

- The performance (volume multiplied by distance) of various long-distance transport alternatives was in 1982 as follows: by truck 46 %, by floating 37 % and by railway 17 %. Natural waterways formed by inland lakes and rivers have been improved for bundle floating. The logging trucks, generally equipped with a full trailer and grapple loader, have an average net load capacity of 30 tons, including the loader.

- There are about 20,000 permanent and 15,000 semipermanent forest workers in Finland. The wages of the forest workers are based primarily on piece rates. In 1982, the average daily earning of a man working with a power-saw was 250 FIM (U.S. $ 40), including the costs from the saw. The employer has to pay an additional 40 % of the worker's wages to cover social security costs.

- The forest industry enterprises buy 75 % of the timber standing. The timber is prepared mainly by company-employed permanent forest workers whereas forest and highway transport is carried out by private contractors, most of whom own one or two forwarders or trucks only. The rest 25 % of timber from private forests is sold delivered to the roadside by the forest owner himself using farm tractor-based equipment.

Figure 3. Wood harvesting is based in Finland on shortwood system. Main part of timber is prepared by permanent forest workers with chain saw.


Figure 4. About 20 % of timber, coming mainly from clear-cutting areas, is prepared by multipurpose machines.

- About 80 % of timber cut by the forest industries and the National Board of Forestry is prepared manually with power-saws. Some 20 %, coming mainly from clear-cutting areas, is cut with multipurpose machines manufactured in Finland or Sweden. At the end of 1984 there were about 250 processors and harvesters in Finland. The trend is towards loader-mounted light processor and harvester equipment.

- The multiple use of forests and general environmental and ecological reasons put increasing pressure on forest management and logging operations. Avoidance of damage to standing trees and forest soil, careful planning and timing of logging, use of natural regeneration where possible and environmental considerations in general are gaining importance and must be acknowledged in the application and development of forest technology.

- A considerable share of timber is measured standing before logging. The measuring unit for all round wood is solid cubic metre including bark, whereas sawmill chips and sawdust are measured as the loose volume of loads.

- The capacity of the integrated forest industries is large enough to process all available timber down to 7 cm (hardwoods) or 6 cm (softwoods) top diameter unless the market situation does not limit the demand. The stumpage price in southern Finland in 1984 was about 160-220 FIM/$m^3$ (≈ 25-35/$m^3$) for saw and veneer logs,

80-90 FIM/$m^3$ (≈ 12-15/$m^3$) for pine and spruce pulpwood and 60-70 FIM/$m^3$ (U.S. ≈ 9-11/$m^3$) for birch pulpwood. The demand for low-quality biomass for energy purposes is also increasing. Consequently, a high recovery level of biomass and maintaining good timber quality are important aspects in logging operations.

- The volume of wood consumed by the wood-processing industry in 1983 totalled 45 million $m^3$. Imported raw material in the form of round wood or sawmill residues accounted for 9 %. In addition, the wood chips from saw and veneer mills (6 million $m^3$), as well as part of the sawdust (3 million $m^3$), were used as secondary raw material by the pulp and the board manufacturing industries. Practically all bark is used for energy production.

- More than half of industrial wood is processed by the pulp and paper industries. In 1983 the production was as follows.

| | Number of mills | Production, tons |
|---|---|---|
| Mechanical pulp | 22 | 2 483 000 |
| Semi-chemical pulp | 3 | 301 000 |
| Sulphite pulp | 8 | 587 000 |
| Sulphate pulp | 18 | 3 792 000 |
| Paper | 30 | 4 825 000 |
| Paper board | 16 | 1 563 000 |

- The production of lumber was 8 million $m^3$ in 1983. A total of 330 commercial sawmills and about 8,000 small local sawmills are in operation. Frame saws are still the most common, but chipper headrigs and band saws are

gaining in importance. Commercial sawmills are traditionally located along the waterways, and rivers and lakes are used for storing and sorting logs.

- There are 26 plywood and veneer mills which produced 580, 000 $m^3$ of birch and birch-faced plywood in 1983. The production of 11 particle board mills was 605,000 $m^3$ and that of 5 fibreboard mills 137,000 tons respectively.

This background information is meant to help the foreign reader to understand the problems and targets of the forest technology research and development programmes in Finland. Another important aspect to be kept in mind is the official and unofficial cooperation with other Finnish and Scandinavian research organizations. Even if the scientific field of the Department of Forest Technology covers in principle the whole sphere of forest work science and wood utilization, industrial wood processing excluded, the shortage of resources and coordination with other institutes restricts the programme to relatively few key areas. Some of them are described below.

# 4 MAJOR RESEARCH SUBJECTS OF THE FOREST OPERATIONS SECTION

## Mechanization of thinning cuttings

Selective thinnings constitute an indispensible part of the Finnish wood production system. At present, 300,000 or even 400,000 ha should be thinned annually. By means of the thinnings, dying and suppressed trees are harvested in order to favour species and individuals of high quality, to speed up the diameter development of trees as well as to enable the forest owner to glean early revenues from the stand.

A low timber yield per unit area, the small size of trees and the avoidance of causing damage to the standing trees additional costs in thinnings. For these reasons the number of thinnings remains at present below target. In the early 1980´s only 140,000 ha of forest area actually underwent thinning opeations annually. If the thinnings are not done the development of the stands suffers and the basis of the wood production system will shatter. Because the large forest areas regenerated during the 1950s and 1960s will be at the thinning stage during the 1990s, the need for early thinnings is growing substantially.

Technical, economic, and ecological aspects are present in the study of the thinning process. Because the questions essentially pertain to the whole field of wood production, research is carried out in close cooperation with the Finnish Forest Research Institute´s other departments as

well as with other Finnish and Scandinavian research institutes.

The Department of Forest Technology has recently studied the use of light-weight forwarders as an alternative to conventional forwarders in timber hauling in the thinning stands. The Department has also studied the suitability of long-range booms for easing the manual harvesting methods. The terrain maneuverability of forwarders on soft bogs and in difficult snow conditions is being studied in 1985 and 1986.

The amount of space needed by different types of machines has been researched through theoretic calculations and on the forest machine simulator at the Suonenjoki Research Station. It is possible to simulate the different machine operations and harvesting conditions on the simulator. For example, a comparative simulator study on felling and bunching with machines which operate on the strip road was carried out.

The amount and quality of stem, root and soil damage caused by farm tractors, forwarders and grapple processors was studied in the beginning of the 1980s. Damage inventories are also carried out in connection with studies dealing with whole-tree and tree section methods.

Figure 5. Selective thinnings constitute an indispensable part of the Finnish wood production system.

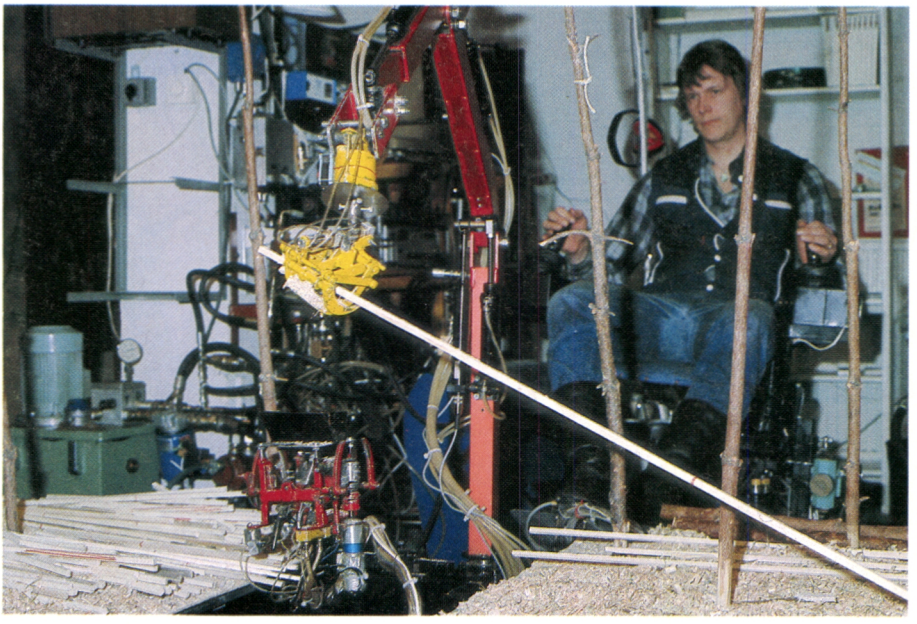

Figure 6. Suitability of different types of machines for thinnings is studied on the forest machine simulator at the Suonenjoki Research Station.

Development of light logging equipment

Traditional logging and regeneration methods experienced drastic changes in the 1960s. The hand saw and axe were replaced with the power-saw. First the farm tractor and then the forwarder took the place of the horse. The number of accidents increased alarmingly as the use of the power-saw became more common.

The development of both the logger´s personal protective-wear and the power-saw safety chain were very important during the 1970s. A quick-fitting, power-saw mountable felling-frame was developed at the Department to ease the felling and bunching of small-sized energy wood when trees are recovered with branches intact. Another study topic is the adaptation of organic rapeseed oil to be used as either motor or chain lubricant on the power-saw.

The short distance haulage of timber is mostly done with forwarders, which, in thinning, require four-meter-wide strip roads placed at 25 - 30 m intervals. In addition, lighter transport equipment may be needed for special purposes. In recent years, the development programme of the Department of Forest Technology has included such equipment as: a portable winch, a horse-skidding device, as well as a light crawler equipped with a hydraulic loader. Experiments on light crawlers are encouraging, especially in thinning operations on bogs.

## Improved recovery of forest biomass

In the middle of the 1960s it became evident that the expansion of the Finnish forest industry would be restricted in the future by a shortage of wood raw material rather than markets or capital. Interest in the utilization of the last biomass reserves - logging residues and small-sized unmerchantable trees - started to grow. Harvesting and the utilization of the entire biomass of the tree were subjected to systematic study. On account of the vital role of the forest industries, this development took place in Finland earlier than in many other industrialized countries.

In 1969, an 8-year joint Nordic research programme led by the Finnish Forest Research Institute was commenced on the recommendation of the Nordic Council in order to obtain additional raw material for the forest industry from branches, tops, stumps and roots. Later on, the programme was continued and expanded in cooperation with the Central Association of Finnish Forest Industries and its member companies. Quantity and properties of unmerchantable biomass were evaluated, and equipment and new harvesting methods were developed and studied. As an example, a logging schedule based on the use of an excavator-mounted stumpharvester and forwarder transport of split pieces of stump and root wood was developed. Different alternatives for the collecting, forwarding and chipping of slash from clear-cutting areas were studied as well.

Figure 7. Harvesting of stump and root wood is being developed to get additional fiber material for the sulphate pulp industries.

Figure 8. Utilization of residual wood as an indigenous energy source is an important research topic in the 1980s.

It gradually became apparent that parallel with the separate harvesting of stumps and slash the concurrent recovery and use of whole-trees holds important advantages for forest management and for the intensive utilization of biomass. The Department of Forest Technology and the Fund for the Jubilee Year 1967 of Finland's Independence (SITRA) launched a 5-year project on "Production, Harvesting and Utilization of Small-Sized Trees" in 1973. The project was supported also by the Academy of Finland.

New small-tree harvesting methods, based primarily on whole-tree chipping, were developed for thinning and clear-cutting conditions. A manual work method combining the felling and bunching of small trees with the help of a felling-frame equipped power-saw, and a mechanized felling and bunching method for the thinning of young pine stands with a small-sized tractor are two examples of the research and development subjects of the project. The roster of subjects also included the forwarding of undelimbed whole-tree raw material, different terrain and landing chipping systems and studies on the upgrading of forest chips.

Harvesting unmerchantable wood for fuel

The harsh climate, long transport distances and the predominance of process-type industries have raised per capita energy consumption in Finland to one of the highest levels in the world. Because Finland has no indigenous fossil fuels the energy self-sufficiency of the country decreased seriously during the 1960s and 1970s. It is worth

mentioning, however, that 16 % of the total consumption of primary energy in Finland is still derived from wood-based fuels, including waste liquor from the chemical pulp industries. This is more than in any other industrialized country.

In order to reduce the dependence on foreign energy, to improve the exploitation of domestic natural resources and to achieve better utilization of rural labour, the Council of State approved the Finnish Energy Policy Programme in 1979 and 1983. The main objectives of the programme are energy conservation and to increase the indigenous energy supply (wood, peat and hydroelectric power). In this context, the Department of Forest Technology changed the emphasis of the then ongoing biomass harvesting program from industrial raw material to indigenous energy.

In 1978 the Finnish Forest Research Institute started a research programme on the production of wood for energy purposes, the so-called PERA project. Its aim is to provide basic information for decision making at the administrative level and to develop practical methods for the production of energy wood in existing forests and special energy plantations. Several research departments work in close cooperation in the project.

The present annual allowable cut of the Finnish forests allows the harvesting of 61 mill. $m^3$ of merchantable stem wood, including bark. If this is realized 5 mill. $m^3$ of small-sized trees and tops, 22 mill. $m^3$ of branches

including foliage and 15 mill. $m^3$ of stumps and roots are simultaneously left unused in the forests. For ecological, technical and economic reasons the recovery of this potential fuel reserve in its entirety is naturally impossible. However, roughly 15 mill. $m^3/a$ of presently unmerchantable biomass, corresponding to 2,9 mill. tons of oil equivalent of energy, is classified as technically harvestable.

Development of harvesting and delivery systems for this renewable fuel reserve is given a high priority in the research and development programme of the Department of Forest Technology. Because of the heterogeneous properties and the small size of trees and tree parts under consideration, the main emphasis of the machine and method development is on harvesting systems based on terrain or landing chipping. In the beginning of the 1980´s, research on fuelwood focussed mainly on the following problem areas:

- Harvesting fuel chips with farm tractor-based equipment for the heating of farm houses
- Harvesting fuel chips with contractor-owned equipment for district heating plants in rural centres
- Harvesting fuel chips with heavy equipment for the power plants of the forest industries either as a separate operation or in connection with the logging of industrial timber
- Improving the quality (moisture content, particle size distribution, etc.) of fuel chips

## The farm tractor as the small scale contractor's logging machine

The 250,000 farm tractors in Finland are insufficiently employed especially in winter time. They can therefore be considered as a potential machine reserve for the logging and hauling of timber also. As a matter of fact, about 5 million $m^3$/a or 75 % of the total volume of delivery sales from private forests is transported by farm tractors.

The Work Efficiency Association (see p. 63) actively studies the use of farm tractors in farm forestry. Nonetheless, the suitability of the heavier farm tractors as a small-scale contractor's basic machine in different kinds of forest operations has not been studied in a wider sense. For example, during the summer months there are more than 1000 farm tractor contractors working in fuel peat production alone and their tractors are poorly employed during the winter season.

Forwarders will without any doubt remain as the basic solution to forest transport in Finland also in the future, but improved efficiency, better ergonomic properties and new auxiliary devices are widening the range of possible applications of farm tractors in forestry as well. In the last few years, the Department of Forest Technology has cooperated with machine manufacturers in the development of various farm tractor-mounted auxiliary equipment; tracks, chippers and a grapple harvester installed in the hydraulic loader boom, for example.

Figure 9. About 25 % of timber is sold delivered to the road side by the forest owner himself using farm tractor-based equipment.

Figure 10. Testing the manoeuvrability and performance of a 4-wheel-drive farm tractor in winter conditions above the arctic circle.

Research is being carried out in cooperation with a joint Nordic project on an improved farm tractor for forestry in the following fields:

- Mapping the requirements and technical and economic possibilities of a farm tractor in logging contracting.
- Studying timber haulage with a farm tractor equipped with a hydraulic loader.
- Studying the mechanized preparation of timber with farm tractor-mounted processors and harvesters.

## Logging on peatlands

The Finnish landscape is characterized by bogs. One third of the productive forest land consists of peatlands. Their total area is 9.4 mill. ha, 44 % of which has been drained. At the moment about 5 mill. $m^3$ of timber is harvested annually from peatlands. As a result of the large-scale drainage programme the amount is expected to rise gradually up to 15 - 20 mill. $m^3$/a by the 2020s. The proportion of timber harvested from peatlands will increase respectively 20 - 25 % of the total drain.

At the beginning, the greatest share of peatland timber will come from thinnings. The poor bearing capacity of the ground and the ditches combined with the general problems of thinning operations make peatland logging problematic.

Figure 11. As a result of a large-scale drainage programme already 5 million $m^3$ of timber is annually available from thinnings on soft peat lands.

Figure 12. A research project on peatland logging gives special attention to development of machines with a very low ground pressure.

A project on peatland logging was launched in 1983. Logging conditions, working methods and existing machinery are being surveyed with the help of Central Forestry Board Tapio, the National Board of Forestry and logging organizations of the forest industry companies. The maneuverability, output and cost level of special machines in peatland conditions are studied as well. The project is participating actively in the development of new equipment and working techniques for peatland logging. Special attention is given to machines with a very low ground pressure.

## Rationalization of silvicultural operations

The total productive forest area of Finland is 19.7 million hectares. With an average rotation age of 80 - 90 years more than 200,000 hectares should be regenerated annually. The area of artificial reforestation was 145,000 ha and that of natural regeneration about 70,000 ha in 1983. The total costs of artificial reforestation amounted to 330 million Finnmarks in 1981.

Mechanical site preparation is applied to practically all clear-cut areas and sometimes also to natural regeneration areas, totally about 130,000 ha annually. About 80 % of the artificial regeneration area is planted and 20 % is direct seeded. All direct seeding is carried out manually after mechanical site preparation. Work studies of artificial regeneration have during the last few

Figure 13. An area of 120,000 ha is regenerated annually by planting. Combination of mechanical site preparation and manual planting is a standard procedure.

Figure 14. Machine planting is studied as a part of the research programme for rationalization of silvicultural operations.

years included manual and machine planting as well as direct seeding by machines.

The responsibilities of the Department of Forest Technology also include work studies of precommercial treatment of young stands. Respacing in young stands was carried out on 290,000 ha in 1981. Pruning of standing trees in order to improve the wood quality was carried out on 11,000 ha in 1983.

In the mid-1970s more than 200,000 ha of forests were fertilized annually. Because of an increase in the prices of fertilizers, the area decreased to 80,000 ha/a in the early 1980s. At the Finnish Forest Research Institute, the work studies on forest fertilization operations are mainly carried out by the Department of Peatland Forestry. A study on the returning of ash from wood and bark fired power plants to agricultural and forest soils has recently been carried out.

Rationalization of nursery operations

Some 250 million trees are planted in forest regeneration areas in Finland annually. In 1981, pine accounted for 82 %, spruce 16 % and other tree species 2 % of the planted stock. The proportion of bare-rooted seedlings was 71 %.

The rationalization of seedling production is an important means of curbing the rise in reforestation costs.

Figure 15. From the ecological point of view prescribed burning is an attractive site preparation method, but the costs are high. New methods are being studied.

Figure 16. A study on the returning of ash from wood and bark fired power plants to agricultural and forest soils is a part of the PERA Project.

Great attention must also be paid to the quality of the seedlings, which affects the success and costs of the whole process of regeneration. The initial growth of containerized seedlings is generally quicker and more certain and the need for aftercare is therefore smaller. The planting season of containerized seedlings is substantially longer and the labour requirement in the nursery is also smaller and more evenly distributed over the year.

The Finnish Forest Research Institute´s nursery studies take place at the Suonenjoki Research Nursery which has a capacity of 3 million seedlings per year. The programme of the Department of Forest Technology includes the technological development of the production of bare-rooted and containerized seedlings. Research is carried out in cooperation with various organisations, e.g., Central Forestry Board Tapio and the District Forestry Boards.

The emphasis of the programme is on the mechanization of nursery work. Containerized seedling production lines, root pruning machines and a seedling hoist are examples of what has been developed and built. In the coming years the programme will include items like the development of drill seeding, transplanting, the techniques of spreading pesticides and the production of bare-rooted seedlings. The research of production technology on containerized nursery stock will be expanded with special emphasis on root pruning of containerized seedlings. The weakening of nursery soil


Figure 17. Developing planting techniques for willow cuttings for the establishment of short-rotation energy plantations.

Figure 18. Rationalization of nursery operations is studied at the Suonenjoki Research Nursery. A prototype machine to produce containerized seedlings with pruned roots.

is being studied in cooperation with various research departments.

## Ergonomic studies

Even in the early 1960s forest work was considered as second-rate. The work was very hard, underpaid, and injury-prone. Since then, tremendous advances have been made on the working conditions, education and wage payment of forest workers, in which ergonomic studies have played an essential part. The wage level exceeds that which is paid in industry, and there is a declining trend in the amount of accidents. The education of workers has been organized and working conditions, equipment and work methods have undergone substantial development. Mechanization has also to some degree changed the nature of forest work.

At present, forest work is considered to be an independent occupation demanding diversified skills. The enhancement of the status of forest work has been important for humane reasons, but it has also been an essential factor in guaranteeing the labour supply for the forest industry.

On principle, ergonomics is a part of every forest work study. It is never the less possible to single out specific research topics that relate directly to ergonomic problems.

The studies on ergonomics are mostly carried out at the Suonenjoki Research Station. The basis is the principle of

the comparative work study, which includes the measurement of the productivity and fatigue of work by accompanying the same worker as he works in different methods and uses different machines.

The main emphasis of ergonomic research was earlier on the study of the work load and strain of loggers. The aim was to develop less fatigying work methods, but attention was naturally also paid to increasing work efficiency. Far-reaching grapple loaders have been in a key position in lightening the short-wood method's heaviest work phase, bunching.

In the past decade, the ergonomic characteristics of forest machines have improved markedly. Because of difficult, uneven forest terrain, whole body vibration and static muscular tension in the shoulder area, which are caused by continuous handling of the controls, continue to remain problems. Noticeable psycho-physiological fatigue may appear as a consequence of neuro-sensory fatigue especially if the workday is long. Wrong eating habits and long working days have also been shown to contribute to over-fatigue.

Forest machinery is undergoing substantial automation development. The affect of automation on neuro-sensory strain is one of the most important study topics for the near future. Another new task is the research of machine operators' training on the basis of the psychology of learning. One means of increasing the effectiveness of

teaching might be through the use of the forest machine simulator at Suonenjoki.

More recent studies have been about the sociological problems of work organization and the ergonomic and hygienic problems of energy wood harvesting (chipping, mould dust, and the spreading of ash). Just recently, a study has been started on the ergonomics of farmers´ own wood harvesting operations. The research deals especially with whole-body vibration on farm tractors when driven in the forest.

## Studies on work safety

In 1970, 11,000 accidents occurred in forest work. The corresponding figure in 1982 was only just over 3600. The development of logger´s personal protective-wear, the improvement of the safety of the power-saw, and the mechanization of forest work have all had a decisive affect on the decrease in the number of accidents. In addition to decreasing the number of accidents, these measures have also affected a change in the nature of accidents.

In Finland, the forestry is nevertheless one of the most dangerous fields of work. The proportion of fatal accidents in field of forestry remains four times greater than in all other fields.

In the 1970s the research work of the Department of Forest Technology aimed at the development of personal

protective-wear and the safety equipment and testing methods of power-saws. At the moment the focus is also on the solving of mental processes connected with the origin of accidents. With the help of the psychological approach, attempts are being made first to examine the reasons for wrong working habits and actions and second to find the means of eliminating them.

## The organization of work in harvesting operations

Harvesting operations consist of various work phases carried out independently by several workers. In Finland, self-managed work groups, who would be responsible for complete realization of harvesting operations, have not become prevalent. Job rotation, where a man could work as a machine operator for some time of the day and then with the power-saw for a time, does not occur. The biggest hindrance to this type of alternative is the dominant piece-rate wage payment system.

In the Department's research, the workers' desire to widen their field of tasks has come to the fore. This could consist of participation in the planning and organization of the harvesting work site, for example. The increased education and occupational skill of workers have made participation in some supervisory tasks possible.

The changes which took place in Finnish society in the 1970s can also be seen in the foremen's field of tasks. The

status and role of supervision have changed because of the need for specialization, increased cooperation and the need for delegating the supervisory tasks.

The Department of Technology, in a joint Nordic project, has mapped out the present tasks, areas of responsibility and time spent by the foremen in various organizations. The aim is to create the conditions for an effective division of labour and sensible work supervision by developing the field of tasks and duties. The need for improvement exists in the following fields especially: operational organization; the education of supervisory skills and principles for planning one´s own work; follow-up; as well as the introduction of ADP to the field and its development in order to lighten the load of office work.

## 5 MAJOR RESEARCH SUBJECTS OF THE WOOD UTILIZATION SECTION

### Wood quality of plantation-grown forests

The present recommendations on the establishment density and tending schedules of plantation-grown forests are intended to ensure as rapid diameter development as possible. Depending on site conditions the original establishment density is 2,000 - 2,500 plants per hectare. The first silvicultural treatment is carried out when the height of the young trees is 1 - 3 m.

Figure 19. Properties of pruned trees are being studied in order to compensate the expected decrease in quality of plantation-grown Scots pine in the future.

Figure 20. Seasoning of saw logs is being studied in cooperation with the Department of Forest Protection.

The Department has been carrying out comparative studies on wood quality in naturally regenerated and plantation-grown forests since the early 1970s. An important problem area is, for instance, the correlation between wood properties and different stand parameters and environmental factors depending on the early development of the trees. Several studies indicate that low initial and growing density and too high a growth rate at the juvenile stage increase the knottiness and other defects in wood. The wood quality seems to be lower in the cultivated stands.

Quality of saw timber

The production of the sawmill industry has remained rather unchanged during the past decades, but its role in the country's economy is still important. Sawn goods account for about 20 % of the value of forest products exports or 9 % of the total value of exports. The profitability of the sawmill industry is today dependent on the availability of high quality raw material, especially pine.

Demand for slowgrown northern softwood lumber is traditionally good in European markets. For the next 40 - 50 years timber will still be harvested mainly from stands which are practically of as high a quality as the stands which exist today. The present trend in forest management to shorter rotation periods and sparser spacings may, however, result in the deterioration of the quality of pine.

The quality of saw timber is a central research subject in the Wood Utilization Section. Most of the work has been done on pine, but attention has also been paid to spruce and birch. A quality classification system of saw logs, based on superficial quality indicators and diameter, was developed already in the 1950s. To facilitate the pricing of saw timber so as to motivate the forest owners to grow high-quality wood, a new grading method, based on tree size and the relative height of the self-pruned portion of the stem, has recently been developed for pine.

## Pruning of trees

As plantation forests are mainly located on the most productive forest lands and in the southern half of the country, their role in wood production will be increasingly important on the national scale. Various means to compensate the expected decrease in wood quality are therefore studied. As far as pine and birch are concerned, one alternative to improve the quality of saw and veneer timber is to prune trees at an early development stage of the stand.

Studies on the quality of pruned trees and pruning techniques were started in the 1950s. In the recent studies the economic aspects of pruning have received more emphasis. In addition to test sawing of pruned butt logs, the quality

of rotary-cut veneer from pruned trees is also studied. Within the next few years, the scope of these studies will be expanded to a more comprehensive project on how the pruning time and environmental factors affect the lumber quality. The work will be carried out partly in cooperation with the other Nordic countries.

Geographic variation of wood properties

The distance from the southern coast of Finland to the northernmost tip of the country is 1,100 km. The properties of wood also vary from area to area being generally better in the south than in the north, and poorer close to the coast than in inland forests. Consequently, the quality and yield of lumber is poorer from the coastal area.

As an example, geo-climatic variation, solar radiation and air temperature affect the number of tracheids and basic density of pine wood. They also affect the amount of branches, size of branches and the amount of needles.

The basic density, which largely determines the utilization properties of wood, decreases in pine from south to north, whereas in spruce it increases with decreasing growth rate towards the north. The stem form and knottiness characteristics become inferior towards the north. The pulp yield is consequently somewhat lower in the north, whereas the yield of by-products is higher in the north as a result of larger heartwood and extractive content.

The wood quality surveys have so far been limited mainly to southern Finland. Within the next few years they will be concentrated more on the northern areas.

## Seasoning of timber

Because the harvesting and storing of timber is carried out throughout the year, timber may be left in the forest and on the landing sites for a long time and, as a result, is exposed to insects, and is liable to discolouration and decay. The quality requirements, however, permit no discolouration or decay in saw and veneer logs, and only to a certain degree in pulp wood. The effect of extended summer storage of both saw logs and pulpwood has been investigated in a search for the correct timing and techniques of storing.

Joint studies in cooperation with the Department of Forest Protection at the Finnish Forest Research Institute and the Finnish Pulp and Paper Research Institute indicate that the storage of saw logs over the entire growing season may decrease the value by as much as one fourth. Extended storage of pulpwood increases the wood loss in chipping, decreases the pulp yield and increases the consumption of bleaching chemicals.

Figure 21. Siberian larch has succeeded best of all the introduced tree species in Finland. To produce high quality wood, however, the young stands must be pruned.

Figure 22. Common birch (Betula pendula) is an important raw material of plywood industry. A research project shall begin concerning the suitability of white birch (Betula pubescens) as a raw material of plywood.

## Properties of foreign tree species

The Finnish forest industries traditionally use domestic pine, spruce and birch as their principal sources of raw material. Alder and aspen are of minor importance only. In addition to domestic timber, 4-5 million $m^3$ raw material is also imported annually from the Soviet Union, other European countries and the USA.

The Finnish Forest Research Institute has also an extensive network of foreign species trials. The most successful exotics are lodgepole pine (Pinus contorta) and Siberian larch (Larix sibirica). Other foreign species are of very little importance.

The Department of Forest Technology has carried out studies on the technical properties and utilization potential of the most important exotics in Finnish conditions. Lodgepole pine, which on certain sites may grow faster than the native species, has turned out to be inferior as a saw timber tree but well suited for sulphate pulping. The technical properties of Siberian larch differ in a number of respects from the Finnish tree species. It is especially suited as decay-resistant construction timber and for making paper of high tearing strength.

## By-products of the mechanical forest industries

The sawmill and plywood industries produce annually large amounts of bark, chips and sawdust as by-products.

measured in loose volume, but experiments on weight scaling and related tests on moisture determination are also in the programme of the Department.

## Timber scaling

In Finland, timber is scaled either while standing or after the preparation of different assortments. Scaling of standing trees is based on the diameter at breast height, tapering and height of the trees. Research in this area belongs traditionally to the Department of Forest Inventory and Yield. On the other hand, research into the measurement of various timber assortments is one of the tasks of the Department of Forest Technology.

In the early 1970s the actual solid volume was introduced almost exclusively as the timber scaling unit. Earlier, cordwood was scaled as the stacked volume of the pile and saw and veneer timber as the technical solid volume based on the top diameter and length of the log. The changeover in the scaling units required extensive studies on log form, the amount of bark and the solid volume content factors. Prior to implementing the changeover the study programme placed emphasis on the conversion factors between different measuring units. Thereafter the main effort was put on developing the scaling methods.

The new scaling system meant a change from the traditional pile volume scaling to a more accurate method in

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Figure 23. Scaling units of sawlogs are based on investigations made on department. Softwood and hardwood logs are scaled on the basis of their length, top diameter and form.

Figure 24. Pulpwood is scaled as a rule in piles at the landing site. A new method developed for scaling for wage payment is based on the length of the frame of the pulpwood bunch and mean length of the bolts.

The most valuable of them is 5 - 6 mill. $m^3$ of pine and spruce sawmill chips which are used for pulping. They are transported from the sawmill mainly by truck, the average distance then being 94 km. They are made of bark-free, clean wood and generally screened at the sawmill. Sawmill chips are an important source of high-quality fibre for the pulp industries.

Some 1,5 mill. $m^3$ of sawdust is used annually by the pulp and board industries. Pulp made of sawdust is comparable with short-fibred hardwood pulp.

The birch and spruce chips produced by the plywood industries are mainly used for chemical pulp, particle boards and fibre boards. The advantages of these chips are high dry matter content and uniform wood properties. Adhesives and large variation in particle size distribution are major disadvantages.

A number of studies on the properties of technical chips and sawdust and the manufacture and transportation of these by-products has been carried out by the Department. The target is to provide research-based information for the production and utilization processes, quality control and scaling. The studies also provide information on the value ratios of the by-products with respect to round wood and conversion coefficients for measurement.

Studies are also carried out for developing measurement techniques of chips and sawdust. At the moment they are

which the pile volume is further converted to solid volume using coefficients depending on the crookedness, branchiness and diameter of the bolts as well as the stacking. During the first few years following its introduction the method worked satisfactorily, but since then the properties of pulpwood piles have changed to such an extent that there is now a need to check the reliability of the method and develop it further.

The pile method mentioned above is only used for 2 - 3 m cordwood in scaling on delivery and scaling for wage payment at the landing site. Present-day harvesting techniques, however, favour long cordwood, but the lack of a generally accepted scaling method constrains the use of this harvesting technique. It therefore is necessary to develop scaling alternatives also for long pulpwood.

A bolt method in which the single bolts are classified into 5-cm top diameter classes was developed to meet the special needs of scaling for wage payment before forest haulage. A bunch method, based on the frame form and mean coefficients of cordwood bunches along the strip road, has also been developed for scaling for wage payment before forest haulage. The practical application and testing of this method will have an important position in scaling studies in the near future.

For softwood saw logs the top diameter is determined in 2-cm classes under bark. The total lengths in the different

Figure 25. Small-sized wood for energy is seasoned in bunches along a strip road.

Figure 26. Different kinds of coverings are studied to decrease the moisture content of whole trees in winter.

diameter classes are converted into actual solid volumes over bark using volume conversion figures. Research results as well as practical experience indicate that there is some systematic error in the present conversion figures. The need for research is further increased by the fact that there is a strong call for a changeover to diameter measurement over bark.

In addition to a possible systematic error in individual saw log lots, the present-day scaling method results in random errors caused by differences in the form of individual stems. The aim of research is to determine the possibility of using correction equations or coefficients based on properties such as the proportion of the butt logs in different lots.

Following the changeover in scaling methods, the work carried out by the Department into conversion factors has declined. Nevertheless, conversions between barked and unbarked wood and the loose volume and solid volume of chips are still important. The amount of bark was elucidated in an extensive nationwide investigation at the 1970s, and there is no immediate need for further research. Conversion figures for chips made of whole trees and logging residues, as well as the suitability of various kinds of scales for the needs of chip trade, will be important research subjects in the near future.

# 6 RELATED RESEARCH INSTITUTES

In Finland, forest research, excluding wood processing and forest industry products, is concentrated mainly at the Finnish Forest Research Institute and the Faculty of Agriculture and Forestry of the University of Helsinki. The share of forest research carried out outside these two organizations is relatively small. Research on forest operations and wood utilization are, however, exceptions.

The Department of Logging and Utilization of Forest Products at the University of Helsinki is responsible for higher education in Forest Technology in Finland. It has two professorships each covering both logging and utilization; one to be held by a professor lecturing in Finnish and another lecturing in Swedish.

Despite limited research resources, the Department has been active in the joint Nordic research programmes especially in the areas of forest terrain classification, transport problems in peatlands, construction and maintenance of forest roads, pruning and wood properties. The cooperation between the University and the Forest Research Institute takes place partly through undergraduate and postgraduate studies of temporary or permanent research personnel. Some staff members of the Institute may occasionally assist in teaching at the University. Another form of cooperation is the provision of laboratory facilities and equipment.

The Department of Forest Products at the Helsinki University of Technology is responsible for higher education in wood processing in Finland. The Department has the following laboratories each headed by a professor: Mechanical Wood Technology, Pulping Technology, Paper Technology, Printing Technology and Wood Chemistry. The main task is teaching. Research deals mainly with forest industry processes and the properties of forest and printing industry products.

The Technical Research Centre of Finland (VTT) maintains 30 laboratories specialized in different fields of technology under the Ministry of Commerce and Industry. The Forest Products Laboratory carries out research on mechanical wood products and their processing. The research field of the Laboratory covers lumber, plywood, particle boards, fibre boards, joinery products, furniture, gluing and preservation. The activities consist of research, testing and product development. The laboratory has a staff of about 30 research officers and 50 other persons. Research on wood, peat and biomass fuels is being done at the Domestic Fuel Laboratory in Jyväskylä in Central Finland and at the Fuel and Lubricant Research Laboratory in Espoo. The number of personnel specialized in domestic fuels in VTT is 90 - 100.

The Finnish Pulp and Paper Research Insitute is the central research institute of the Finnish pulp, paper and paperboard industries. The research covers the whole field

of pulp and paper manufacturing from the raw material to the end product, including by-products. The Institute has 300 employees, 90 of which are graduated research officers.

The main function is to carry out technical and scientific research on the raw material, processes and products of the pulp and paper industries and to promote technology in these fields. Examples of the research cooperation between the Department of Forest Technology and the Pulp and Paper Research Institute are test pulpings of sawmill chips, whole-tree raw material, decay-defected pulpwood and exotics.

Metsäteho, the Forest Work Study Section of the Central Association of Finnish Forest Industries, is a private research organization maintained and financed by the forest industries. The total number of staff is 36, including 14 research officers.

The function of Metsäteho is to develop and rationalize forest work methods for the needs of the forest industries through investigations, machine tests and by distributing information to the member companies. The main emphasis is on logging. In addition, silvicultural operations and scaling of timber are also included in the programme. The central areas of interest are the development of new work methods, mechanization, and wage scales as well as the planning and control methods for the effective and economic use of resources.

The Forestry Department of the Work Efficiency Association, Työtehoseura, is a private organization enjoying state support. The Association aims at the rationalization of agriculture, forestry and home economics. The forestry sector consists of the Forestry Department in Helsinki and the Forest Experiment Station at Rajamäki. The Forestry Department has 13 research officers.

The main interest of Työtehoseura is in rationalizing forest operations in small-scale farm forestry. Important problem areas are the thinning, harvesting and conversion of fuelwood, the use of farm tractors in logging work, ergonomic problems and development of soil preparation machines.

In addition to the organizations mentioned before, forest machine testing is carried out by VAKOLA, Finnish Research Institute of Engineering in Agriculture and Forestry. Moreover, the National Board of Forestry has its own Mechanization and Work Study Section in northern Finland at Hirvas for introducing, testing and developing forest work methods mainly for the large-scale operations in the northern state-owned forests.

Forest operations research is often connected in one way or another with machine development and testing as well as with the introduction and application of research results in practical forestry. The immediate needs of different parties differ, giving thus a good reason for having several organizations for forest operations research in Finland.

The existence of several active organizations in the same scientific field naturally creates a danger of unnecessary overlapping. To avoid this, representatives of these organizations meet regularly under the umbrella of the Cooperation Committee for Forest Technology Research set up by the Society of Forestry in Finland to discuss the research programmes and problems of common interest in general. As a result of the cooperation each institute is able to concentrate its resources more effectively on a few key areas.

# 7 MAJOR PUBLICATIONS IN 1970-1984

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1970:

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HARSTELA, Pertti. Kasausajan ja valtimonlyöntitiheyden sekä tehollisen sahausajan määrittäminen järjestettyjen kokeiden, pulssitutkimuksen ja frekvenssianalyysin avulla. Summary: Determination of pulse repetition frequency and effective sawing time with set tests pulse study and frequency analysis. Folia For. 80:1-14.

-------- The effect of winter conditions on the preparation of rough-limbed spruce pulpwood of approximate length. Tiivistelmä: Talviolosuhteiden vaikutus tynkäkarsitun ja likipituisen kuusikuitupuun tekoon. Commun. Inst. For. Fenn. 71(4):1-54.

-------- & RUOSTE, Teemu. Kokonaisten puiden esijuonto kaksirumpuvintturilla käytävä- ja riviharvennuksessa. Laitteiden ja menetelmien kehittelyä sekä tuotoskokeita. Summary: Preliminary full-tree skidding by two drum winch in strip and row thinning. Folia For. 91:1-28.

1971:

AHO, Kauko & RANTAPUU, Klaus. Metsätraktorien veto- ja nousukyvystä rinteessä. Summary: On slope elevation performance for forest tractors. Folia For. 111:1-17.

AHONEN, Matti. Tutkimuksia kanto- ja juuripuun korjuusta I. Kokeilu puiden kaatamisesta juurakkoineen. Summary: Studies on the harvesting of stumps and roots in Finland I. Experiment with the felling of trees with their rootstock. Folia For. 103:1-16.

HAKKILA, Pentti. Puutavaran vaurioitumisesta leikkuuterää korjuutyössä käytettäessä. Summary: On the wood damage caused by shear blade in logging work. Folia For. 108:1-15.

HARSTELA, Pertti. Moottorisahan tärinän vaikutuksesta työntekijän käsiin. Summary: On the effect of motor saw vibration on the hands of forest worker. Folia For. 118:1-14.

-------- Puunkorjuumenetelmien ergonominen kehitys ja eräät työntekijään kohdistuvat fyysiset vaikutukset. Sum-

mary: The ergonomic development of the timber harvesting work methods and some physic effects on workers. Folia For. 131:1-22.
-------- Työjärjestyksen vaikutus tynkäkarsitun ja likipituisen kuusikuitupuun teossa. Summary: The effect of the sequence of work on the preparation of approximately 3-m, rough-limbed spruce pulpwood. Folia For. 105:1-23.

1972:

AHONEN, Matti. Rough-limbing and ocular marking for crosscutting in the preparation of sawlogs of pine. Seloste: Tynkäkarsinnan ja silmävaraisen apteerauksen vaikutuksesta mäntysahapuiden tekoon. Commun. Inst. For. Fenn. 73(5):1-93.
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