Research in Forest and Wood Science in Finland

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Boreal Finland

Finland is located within the boreal coniferous zone between the 60th and 70th parallels. Thanks to the ameliorating influence of the warm Gulf Stream in the North Atlantic, the growing conditions for forests are more favourable here than far north anywhere else. The main limitation to forest growth is climate. The growing season is fairly short although the differences between the northern and southern parts of the country are considerable. Finland's northerly location shows in the long rotation times; 50-80 years are required at the least for forests to reach a maturity. As natural disturbances like fires, insect attacks or storms cause a new rotation to start in a natural ecosystem, the boreal forests consisting of these species are often called catastrophic ecosystems.

There are over 20 indigenous tree species growing in Finland, but only a few of them are commercially valuable: Scots pine (Pinus sylvestris), Norway spruce (Picea abies) and two birch species (Betula pendula and B. pubescens).

The northern humid conditions in Finland are reflected in the high proportion of peatlands of the total forested area. In certain regions of the country their proportion can be up to 60% of the land area.

Sources: The Finnish Forest Research Institute
The Finnish Meteorological Institute
Introduction

The Finnish Society of Forest Science was established in 1909 to promote research in forest and wood sciences in Finland. As one form of this activity the Society wants to give a brief state-of-the-art picture of what is going on in Finland in the forestry-related studies at the moment. We hope that this publication will serve both as a short introduction to forest and wood science in Finland and as a handy source of useful contact information about Finnish scientists in this field.

The first part briefly takes the reader through the historical development of our forest research from its beginning to the present. It also gives a short account of the role of forestry related research in Finland and future perspectives in the field. It is our hope that this will help to clarify why some things are focused on in our research and others are less important. The first part also tries to sketch our role on the international front as seen through Finnish eyes.

The second part gives a more detailed description of what the main issues at the moment in research in forest and wood science in Finland are. The chapter is divided into ecological, management and economical forest sciences and wood sciences.

The third part gives a brief introduction to the main research organizations active in forest and wood science. At the end of this part we have included a list of organizations associated with research activities in Finland.

Finally, the Society wishes to thank all those people that participated in making this presentation.

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Continuity and Change in Finnish Forest Sciences

Prologue

It is fair to assume that forest sciences, like any other human activity, are tradition and context-bound. This means that forest sciences do not develop in a vacuum but are affected by national and international developments in corresponding and related sciences and by political, socioeconomic and cultural factors. Of course, the talents of individual scientists have a fundamental role in scientific development but it could also be claimed that many scientific ideas are the products of their era. Therefore, a key to understanding the present and future trends in forest sciences lies in knowing the development that has led to the present situation. The purpose of this introductory chapter is firstly to review the historical and past developments in Finnish forest sciences, secondly to introduce the role of Finnish forest sciences in the international perspective, and thirdly, to outline some future challenges in this field.

From tar-culture to biodiversity

Early days

The Finns have traditionally had a particularly intimate relationship with the forests. Their subsistence and the later economic development have been largely based on forest resources. Even the cultural heritage by authors, painters, composers and by sportsmen is forest-bound.

Three-quarters of the land area of Finland is covered by forests. No wonder that the first agriculture was to a great extent shifting cultivation and foreign trade was based on the building of wooden ships and tar distillation. The majority of the Finnish forests have thus been under heavy human influence even before modern forestry practices started, unlike the large untouched boreal forest areas in Canada and Siberia. Fears had already been expressed on the sustainability of Finnish forestry by the early 19th century.

Against that background it is not surprising that the beginning of forest research in Finland dates back to the 18th century and the Enlightenment. Pehr Kalm, the first professor of economics of the University of Helsinki, established about a hundred years previously in Turku in 1640, and his students started to analyse the actual forestry problems of the time. However, it was only after Mestähallitus, presently the Finnish Forest and Park Service became established first temporarily in 1851 and permanently later in the same decade that more organised forest education and research was mobilized.

Breakthrough

Whereas the 18th century brought the idea that forestry issues can be approached by the means of research and development and the 19th century planted the seeds of these activities, the beginning of the 20th century saw the breakthrough in forest sciences in Finland.

At the beginning of the 20th century Finnish society had to face many drastic changes. After 108 years of autonomous rule under the Russian Empire, Finland gained her independence. In this situation the forests, as the most important renewable natural resource of the country, played a central role. An extensive land reform combined with large-scale settlement activities were
launched which changed the ownership pattern of the Finnish forests. The number of the small-size woodlots owned mostly by farmers increased considerably.

The sawmilling industry had expanded rapidly in Finland since the 1870s and the pulp and paper industry had followed its lead. Forest products as a proportion of the total value of exports had risen simultaneously from about 50 to 80 percent which increased domestic worry about large-scale deforestation and provided economic incentive to invest in forest research. A change to sustainable forest management systems that would maintain forests and their production potential became desirable. As a preventive measure, a new forestry act was passed in 1917 that obliged the woodlot owner to guarantee forest regeneration.

During the period from 1908 to 1917, when Finland was still united to the Russian Empire, many important steps were taken. Higher education in forestry was first transferred from the isolated Forestry College of Evo to the University of Helsinki. The Finnish Society of Forest Science was established in 1909 and the Finnish Forest Research Institute (METLA) was created in 1917.

Initially higher education in forestry took its example from universities and forest research institutes in Germany, Sweden and Russia. Initial enthusiasm produced ten doctors during the ten first years of university education. The high level of some basic sciences, for example botany, was reflected in the rapid mobilization of forest research. The publication series Acta Forestalia Fennica by the Finnish Society of Forest Science and the Communications Instituti Forestali Fenniae by the Finnish Forest Research Institute were begun.

A.K. Cajander created his theory of forest types, and was the main figure in the initial organization of forest sciences in Finland. Werner Cajanus pioneered statistical-mathematical methods in forest mensuration and inventory. Olli Heikinheimo was early enough to conduct an empirical survey on shifting cultivation and its impact on forest resources.

**Early promotion of timber production**

During the 1920’s forest products as a proportion of the total value of exports grew to 85 percent. Thus forestry and forest industries had a dominating role in economic development. The government responded to this situation by establishing university education and research and development (R&D) units for forest industries at Helsinki University of Technology in 1908 and the Technical Research Centre of Finland. Also Forest industry founded the Finnish Puls and Paper Research Institute in 1916.

Since the latter half of the 19th century, a number of committees had studied the threats to sustainable timber production. However, the answer remained uncertain, until 1924 when the pilot results from the first national inventory of forest resources were published. Väyö Ilvesalo completed this and the three subsequent inventories. Finland was the first country in the world to complete an objective and scientific nation-wide forest inventory. Väyö Ilvesalo himself became both nationally and internationally well-known. At the foundation of the Academy of Finland at the end of 1940s he became one of the twelve first academicians, the highest honour conferred on scientist of those days.

The long-lived timber sustainability issue was finally solved in the 1930s when Eino Saari, the first professor of forest policy at Helsinki University, lead the first nation-wide survey of wood utilization in the Finnish Forest Research Institute. The timber drain-potential sustainable cut - relationship appeared more favourable than had been feared.

Most of the silvicultural research during the first part of the 20th century was based on A.K. Cajander’s theory of site type classification based on the species composition of the ground vegetation. It achieved the status of a strong paradigm in Finland. Cajander himself was the most prominent Finnish forest scientist during the 1910s and the 1920s. In the 1920s he was nominated as director general of the National Board of Forestry (Metsähallitus) and, later on, was three times prime minister of Finland. Some other forest scientists such as Mauno Pekkala (also prime minister), N.A. Osara and Eino Saari were cabinet ministers which indicated that the pioneering forest sciences played a strategic and appreciated role in Finnish society.

In a nutshell, the early years of the twentieth century were characterized by high enthusiasm in this new field of science. Although only a few highlights are brought forward the same applied to the whole field of forest and wood sciences. The bases for future work were laid during those days. Perhaps the threat to sustainable forestry that had been experienced since the 19th century has shaped subsequent forest research from the outset.

**Supporting national forestry planning**

The Second World War slowed down forest research to a considerable degree. A resurgence occurred towards the end of the 1950s and in particular during the 1960s. After the War Finland depended heavily on her forest-based exports. Forest products were 90 percent of the value of exports during the early 1950s, but started to decline thereafter due to structural changes in the Finnish economy. However, the expansion of forest industries had still a key role in supporting economic growth and employment. No wonder that a strong signal was given to forest research as, the Finnish Forest Research Institute again warned that the sustainable cut was threatened at the beginning of the 1960s.
The Finnish Forest Research Institute forest resource accounting system found that the annual cut exceeded the sustained yield potentials. The cut from non-industrial private forests (NIPF) especially showed an alarming trend. This gave rise to a number of forest policy and forest investment programs that would increase timber growth. Decreasing the cut was not an option in the economic situation of those days.

An intensive period of nearly three decades of national forestry planning was begun. New challenges were set for forest research to support the strategic planning and implementation activities. When the nationally crucial sustainable timber production was at stake, research on intensifying forestry management was increased.

Silvicultural research was directed to study seed supply, forest genetics, nursery techniques, regeneration by planting and sowing, precommercial tending of plantations, fertilization and various other silvicultural regimes. Petri Mikola, Risto Sarvas, Piaavo Yli-Vakkuri and Gustaf Sirén were, among others, the principal promoters of research in this field.

One third of the land area of Finland is peatland. Research on peatland forestry was intensified considerably during this period due to their great timber production potential after drainage. Site classification of mires, their wood growth and yield, draining techniques and machines, fertilization and the profitability of mire drainage all came under intensified research. Professors O.J. Lukkala from the Finnish Forest Research institute initially and later Leo Heikurainen of the University of Helsinki had a leading role in the development of the research and teaching in this field.

National sustainable timber production planning was also developed along with the new challenges to forestry planning. The concept of sustainable forestry was expanded from simple growth and drain studies to include the idea of calculating the allowable cut for a period of future rotation. Vilho Lihtonen, Kullervo Kuusela and Aarno Nyysönen were leaders in this change.

The concept of planning optimal forest production was subsequently introduced. The development of computing capacity facilitated simulation of large number of different regime options from which an optimal combination could be selected through linear programming. Professor Pekka Kilikki of the University of Joensuu was the forerunner in applying these methods to forestry in Finland.

The scarcity of sustainable cut set new requirements for the accuracy of forest inventory methods. Technological change also facilitated higher productivity. The remote sensing technologies for forest resource assessment were applied at an early stage by international standards from the late 1960s by Simo Posa, later the professor of forest inventory and management in the University of Helsinki, and these were subsequently introduced to the national forest inventory. By the 1990s a new multiscore forest monitoring system has been developed in the Finnish Forest Research Institute. This has become internationally appreciated and its applications been implemented or are being seriously considered for example in China, Chile and New Zealand.

The rapid post-war technological change affected logging operations, which have become highly mechanized in Finland since the 1950s. Professor Pentti Hakkilä of the Finnish Forest Research Institute is among the most well known Finnish scientists in the field. Hakkilä is presently a member of the IUFRO Board. The role of machine manufacturing companies has been dominant in the advancement of logging systems. Metsähö, a privately funded R&D body has been an active developer of mechanized operations in logging and silviculture for half a century.

Along with the research into improving the production potential of the forests and their optimal management studies on the amount, structure, social conditions and training of the forest labour were also conducted. A school of related studies grew around Lauri Heikinheimo from the Finnish Forest Research Institute. This kind of strong research tradition may not have had a parallel abroad and a part of Finland’s success in forestry is due to these studies. The sampling method developed by Heikinheimo became adapted as a general method to survey labour force by the Ministry of Labour.

A particular feature of Finland is the large number of small-scale forest owners. This showed in the research as a need to understand their motives for practicing forestry and what national-level consequences these might have. This was manifested particularly when the general wish was to intensify forestry. Since the 1960s family owners have been surveyed and analysed sociologically and economically more frequently in Finland than perhaps in any other country. Professors Päiviö Rihinen and Kauko Haltola had a great impact on these studies.

As a result of the policy focusing on timber production investment, the growth of the Finnish forests and the cutting potential began to increase significantly, as was desired. Active research together with forest policies and intensive silvicultural measures have resulted in a 22% increase in the growing stock and a 44% increase in the total annual growth since 1950. The roots of many research projects still carried out today date back to this period of intensifying forestry.

Towards biodiversity promotion

Intensive national forestry planning led to large-scale forestry management intensification activities. The scarcity of sustainable timber supply and excess cut situation in the 1960s has later been fundamentally transformed into the opposite. In the new situation the sustainable cut exceeds the actual timber drain markedly. Accordingly, econometric research on supply of and demand for roundwood has been considerably expanded. The profitability of forestry has also been enhanced. The investigation in this front has gained international recognition.
International interaction

Early development

The international impact of forest research cannot be so tightly coupled with practical forestry problems they can in a national perspective. Its impact arises mainly through the merit of the work done. Naturally, the problems facing forestry are partially the same internationally and the exchange of experiences between countries in different phases of the development of their forestry sectors are beneficial. Natural co-operation occurs when similar problems are experienced simultaneously in different countries. On the other hand, many environmental, ecological and economic questions are global and attract simultaneous attention in a number of countries.

In the history of Finnish international interaction in forest and wood sciences one can perhaps distinguish three phases: initiation, expansion and establishment. In the early phases Finnish forestry specialists were mainly learning from the experiences of other countries. Although Pehr Kalm, in the middle of the 18th century, made his famous fact-finding tour to North America with essentially forests in mind, the main international connections were established by A.G. Blomqvist along with a number of his mid 19th century contemporaries who were educated as foresters abroad primarily in Germany, Sweden and Russia.

The first great Finnish undertakings on the international front took place in the late 19th century and at the beginning of the 20th century just as in the fields of the arts and sport. This coincided with the awakening of Finnish nationalism. The new nation wanted to show its worth on the international front. Finnish artists such as Akseli Gallen-Kallela and Albert Edelfelt and composers lead by the example of Jean Sibelius started to create a Finnish national romantic style. At the same time Finnish runners such as Hannes Kolmelainen and Paavo Nurmi made the name of Finland known at the Olympic games.

Comparably famous persons in the field of forest sciences were A.K. Cajander and Werner Cajanus. Cajander developed his forest-type theory and Cajanus was among the forerunners in the use of statistical methods in forest sciences on a global scale. When Cajander became the prime minister of Finland he was in the position not only to increase research funding but also promote visits by a number of scientists to Central Europe, North America and even as far away as Argentina to test his theory of forest types empirically. His ideas were well regarded internationally and he became widely known. Cajander was later nominated the honorary president of IUFRO in 1936.

The setting up and implementation of the first national forest inventory was a fruitful scientific interaction between Norway, Sweden and Finland. The joint development of the inventory sampling method was glorious since it was preceeding the creation of the theory of systematic sampling in general statistics. On the same lines a comprehensive study of the “World’s forest resources and timber utilization” became completed in 1934 only the second in the world.

The first Finnish specialist in soil science, V.T. Aallon on wrote a number of textbooks published in Germany which were widely used for teaching, not just in Russian universities. The principal publishing language apart from Finnish was German rather than English among the pioneering Finnish forest researchers. This followed the international practice during this period.

Erkki Linnroth became nominated as a professor of forest inventory and management planning at the University of Helsinki in 1927. About 10 years later he became the president of IUFRO. The World Congress of IUFRO was intended to be organized in Helsinki in 1940. Due to the war it was postponed by several years and Linnroth became the longest president office holder in the history of IUFRO. The congress was never organized in Helsinki but finally after more than half a century later in Tampere in 1995.
Eino Saari has left his mark in many international contexts. Perhaps the most important for the advancement of forest sciences was his chairmanship of the joint IUFRO/FAO Committee for developing the Oxford Decimal Classification System for forestry libraries during the 1950s. Saari also strongly promoted scientific co-operation between Finland and the United States as a chairman of the corresponding committee during the 1950s and 1960s. A large number of Finnish graduate students and forest scientists received scholarships to various universities in the USA which has promoted the scientific cooperation between the two countries greatly.

Professor N.A. Osara of the Finnish Forest Research Institute was nominated as the Assistant Director-General of the Forestry Department of FAO in Rome in the 1960s. In this position he was able to promote research and education particularly in the developing countries.

Co-operation with our neighbours

As a consequence of the pioneering work of its early forest scientists, Finland became internationally established in this field. Intensive co-operation among neighbouring countries has been typical to Finland since the beginning. The Scandinavian countries have presently about 20 joint forest research associations. They are coordinated and jointly funded by the Board of Cooperation on the Nordic Forest Research. Researchers in forest engineering have had the most numerous Scandinavian-funded joint research projects. Different sectorial organizations, such as the Scandinavian Society of Forest Economics, have meetings and ad hoc seminars and produce various publications. A joint publication, the Scandinavian Journal of Forest Research, which covers all fields of forest science has been published for about ten years and another one, The Journal of Forest Economics has been started recently.

Another line of cooperation has been between Finland and Soviet Union / Russia and the previous SEV / COMECOM- countries. Long-term projects to study the production ecology of forests have been carried out as a Finnish-Soviet joint project with Russian and Estonian scientists. Recently the most intensive interaction has been with the Baltic countries and Russia. The special problems caused by the pollution from the Kola Peninsula mineral refineries has been studied jointly by Finnish and Russian scientists. The University of Joensuu has devoted specific efforts to promote cooperation with St. Petersburg and Petrozavodsk. Mutually organized scientific exchanges, excursions, seminars and joint research projects have frequently taken place.

The European connections

Traditionally Finnish forest research has followed the experiences gained in the Central European countries. More recently international co-operation projects funded by the European Science Foundation and European Union have become an important part of the scientific work carried out in Finland. Since Finland entered the European Union as a full member in 1995 our international cooperation and funding has started to reorientate itself still further towards the EU member countries. A large number of projects have been undertaken with joint financing from Brussels.

Finland set up the European Forest Institute (EFI) in 1993 to coordinate and implement pan-European forest research. EFI presently has 43 member organizations from 25 European member countries. It has become an international NGO with its headquarters in Joensuu. Dr. Birger Solberg from Norway has been appointed its first director. EFI has put special emphasis in studying the development of European forest resources and the boreal forest zone as a whole under the leadership of Kullervo Kuusela.

International products

A number of visiting Finnish forest scientists have contributed to the work of the International Institute of Applied Systems Analysis, IIASA in Austria. Among the well-known contributions is the "Global Forest Sector Trade Model" which was developed in 1980s by a large international team of scientists lead by professors Risto Seppälä from the Finnish Forest Research Institute and Markku Kallio from the Helsinki School of Economics.

R&D in forest products and machinery has also been widely implemented by companies and their joint bodies such as the Pulp and Paper Research Institute and Metsäteko (The R&D De-
department for Timber Procurement and Production at the Finnish Forest Industries Federation). Numerous patents abroad, increasing export of machinery for the production of pulp, paper, lumber, plywood and in logging are the best proofs of the international competitiveness of the R&D sector in this field. Finland has become one of the leading countries in paper and logging machine exports as well as in consulting where companies such as the Jaakko Pöyry Corporation have made global breakthrough.

Sharing the experiences

FINNIDA - the Finnish Development Agency, the Academy of Finland and the Helsinki-based World Institute of Development Economics Research UNU/WIDER have been funding and promoting research concerning developing countries. Finland has, for example, supported FAO's recent "Global Forest Resources 1990 Assessment". Long standing cooperation between Thailand and Finland has resulted in about ten Thai doctoral theses in the University of Helsinki. Indonesia, Kenya, Sudan, Tanzania and Mexico have also had extensive cooperation with the University of Helsinki. The Finnish Forest Research Institute has been developing research cooperation between Brazil, Chile and Ethiopia while the University of Joensuu has mainly focused on co-operation with the Philippines and Namibia. Modelling studies of tropical deforestation by the Finnish Forest Research Institute have covered the whole of the Tropical World.

Perspectives for the future

During the first half of the 1990s the public funding of forest research has declined by nearly 20 percent. Further pressure to seek more funding from the private sector and contracts is under way. Various organizational changes have aimed at increased productivity. The same has been targeted by numerous evaluations of research programs and fields. It can be expected that public funding is still going to be decreased do the various research directors not take a strong public stand on this issue.

Forestry research in Finland serves not only forest industry corporations and the government but also numerous rural and urban families as non-industrial forest owners, consumers and citizens at large. This multiplicity of clients and increasing responsibilities in environmental research are the main reasons why public financing of forest research in Finland is expected to maintain its principal role in the future. This is particularly important in safeguarding adequate funding of basic forest sciences. The success of applied research and development work depends crucially on the high quality of associated basic sciences.

Forest research could be directed to support the information needs of future forest and environmental policy transformations better. Since unemployment has become one of the most serious national worries, future forest research is also expected to contribute to generation of new employment. This could be done through product development and other support for entrepreneurship in the forest sector.

The Ministry of Agriculture and Forestry published recently a committee report on research policy in forestry. The purpose of the committee was to safeguard the production of strategic forest research results deriving from unforeseen external changes in the forest sector. The committee defined the mission of forestry research as producing scientifically high standard, problem-oriented and program-based results.

Epilogue

The national innovation system is defined as composed of the interaction of innovation search and learning by doing. The former includes interaction of public and private R&D, education, training and extension. The latter is composed of interaction in R&D, production and marketing within and among business corporations. A well-functioning national innovation system is expected to produce industrial, social, organizational and cultural innovations to promote human welfare efficiently. This concept means that R&D in the forest sector could also be viewed from a more holistic and interactive angle. This is a major national challenge in the future for Finnish forest sciences.

Finland’s membership in the European Union, globalization of forest products trade and forest policy and the widening gap between developed and developing countries in R&D and knowledge both set demanding and growing requirements for international cooperation in the forest and wood sciences. The increase in scientifi c exchange as well as of international funding and joint
research projects are major international challenges that the scientists in Finland have to meet. We can claim that we are arriving at an era of global forest sciences at the time when we have the privilege of organizing the IUFRO World Congress and when IUFRO is taking its first steps in another century of its existence. With no doubt, forest sciences in Finland have grown along with IUFRO and greatly benefited from its international linkages.
The Laws of Nature Rule in the Forests: ecologically-oriented forest research in Finland

Silvicultural research solves forest management problems

As the previous chapter outlined, the tradition of Finnish foresters aiming for improving wood production dates back to the early days of the 20th century. In line with this, silvicultural research has focused on the development of efficient management and regeneration methods.

Forestry in Finland is characterized by the high proportion of privately owned forests. Nearly two-thirds of the forest area is private woodlots, hence the average treatment units is only 2-3 ha. Research on forest management has consequently concentrated on methods applicable to small-scale forestry. The effects of thinnings on growth and yield, and the economics and techniques of thinning have attracted particular interest. Historically forest regeneration research has also had high priority in Finland. Its results are internationally recognized and have been applied throughout the Boreal forest zone as well as in the establishment of plantations in the Tropics.

Forest research has close connections with private forestry, state forestry and forest industry in the form of cooperative research committees and working parties. Numerous new ideas for research tasks have been developed through joint efforts with practical forestry. Many experimental plots have also been established by the collaborating parties. The extension service in research is intensive, and the latest research results are transferred without delay to the forestry practice in seminars, excursions and written articles.

The multidisciplinary approach combining the biological, economic and technical sciences have been successfully applied in expert analysis systems (e.g. Viljo) developed to combine forest regeneration methods. Another excellent example of cooperation in research and forestry

Seedling production is one of the cornerstones of silviculture

Research into tree seedling production and nursery problems serves as an example of applied, practice-oriented research. In the Suonenjoki Research Nursery of the Finnish Forest Research Institute both research and commercial plant production are practiced. This unique arrangement makes it possible for research to immediately meet the actual problems of plant production and artificial forest regeneration.
practice is the monitoring of forest insect pest populations. Fluctuations in population sizes can be predicted and forestry practice can take action to avoid major damage.

While wood production has been the main driving force in forestry, Finns have always found their way to the forest. This is reflected in forest research. The by-products of forestry as well as the recreational use of forests have been subject to growing interest in the forest research community. A nationwide inventory of the recreational use of forests is being launched and investigations of changes in forestry planning and management methods towards strategies that are more generally accepted have received more emphasis.

Long term monitoring is a strength in forest research

The research forests serve as a physical data base for forest research. Experiments in them can be maintained and monitored for decades. They also provide information and potential for international cooperation in comparisons of forest management methods and for research into the variation in tree growth in different climatic conditions. The network of research forests allows research in a wide variety of different land use categories and in a continuum of forest management purposes. The strict nature conservation areas provide excellent research potential and a good comparison with production forests.

The Finnish Forest Research Institute has numerous old experiments in its research forests. They include for instance provenance trials as well as studies on seed and litter production, fertilization and ditching, stand dynamics, thinning and harvesting, and growth trends of forest trees. They have provided forest scientists with indispensable information on forests and forest management during decades.

Well-established and continuously maintained long-term experiments are valuable when research is facing new problems. For example, the fertilization experiments that were essential during the 1960s and 1970s for fertilization purposes have turned out to be crucial in studying the effects of air pollutants on forest soil. Another excellent example of the multifunctional use of old experiments are the provenance trials established in 1920s and 1930s, originally to study the adaptation of trees to new growing conditions. Nowadays, they serve as an information base for global climate change studies as well as species diversity.

New focus on forest biodiversity

Trees and stand structure are in close interaction with all other parts of the forest ecosystem, e.g. soil, flora and fauna. Studies of stand structure and dynamic development processes at stand level therefore play a key role in the identification of biodiversity indicators in different forest vegetation types. The protected forests of the forest conservation areas are the major remaining samples of undisturbed forests, and are therefore the basic experimental forests for research on biodiversity. They are complemented by a large number of long-term permanent sampling plots in the experimental forests.

Many of the species that have become rare under the efficient forest management live on dead and decaying wood. These species themselves are often harmless to wood production. However, leaving dead trees in the forest always involves, at least temporarily, an increase in pest species populations. A key issue is therefore to determine the range within which the populations of pest species can be allowed to grow without causing serious damage to the growing stock, and what proportions of dying wood this requires. Another factor that needs to be considered is the possible effect of climate change on the growth and reproduction of these populations.

Open issues include regional variation in biodiversity, the mosaic structure and size variation of compartments (stands) forming larger forest entities, the role of compartment edges for animal species, and the factors influencing the occurrence of species dependent on forest fires and forest management practices such as prescribed burning.

In response to the requirement of forest management mimicking natural stand development processes, there has been a revival of research into the natural succession of forests, last a subject of intensive research in the early part of the century. The descriptive approach of those days has now been replaced by more analytical methods studying the dependence of regeneration and development on the physical environment. Projects are currently underway to shed light on the differentiation of tree structures and the development of species composition in the natural boreal forest. Studies on regeneration and the population biology of the main species have been comprehensive since last century but new emphases need to be put on the effects of spatial heterogeneity on these aspects.

Environmental concern in forestry: the quality of water, soil productivity and the threat of changing climate

Forestry operations affect water quality

Finland is a mosaic of forests and lakes. Forests and forestry have a direct effect on the functioning and structure of the aquatic ecosystems characterised by shallow lakes surrounded by forests. Forestry practices such as cuttings, soil preparation and drainage have an impact on water ecosystems in the form of eutrophication, discoloration of water and silting, with major effects on the clean water resources, fish populations and recreational values of lakes and rivers.

The ultimate goal is to reduce the nutrient and particle load on the aquatic ecosystems. This implies that in forestry the conservation of aquatic ecosystems is an integral part of the management of the forest resources. For example, buffer zones capable of reducing surface flow and absorbing nutrients are urgently needed around lakes and rivers. Similarly, the soil preparation methods with a minimum disturbance of the nutrient cycle in forest lands reduce the nutrient load on aquatic ecosystems.
Are air borne impurities affecting soil productivity?

The site productivity in terms of the undisturbed nutrient cycle is the core of sustainability in forestry. The removal of nutrients in timber harvesting and acidification of forest soil due to air borne impurities are among the main threats to the productivity of the forest ecosystems. In Finland, air borne impurities are a particular threat in southern Finland, but the forests in northern Finland far from the main sources of the air pollutants are also affected.

Uptill now, the nutrients from weathering of the parent material have compensated for the effects of timber harvest as demonstrated in many studies. Similarly, the acclifying substances (sulfur and nitrogen compounds) are mainly neutralised by the base cations readily available in the forest soil thanks to the young soil profile dating back to about 10,000 years ago when the continental ice masses retreated.

Climate change: threat to forestry?

Finland is among the countries where the climate is most likely to change substantially. This implies that in Finland the annual mean temperature could increase 2-4°C. During the winter-time, the temperature increase would be especially dramatic; i.e. 6-8°C if the global prediction of the temperature elevation comes true. This implies longer growing seasons and larger precipitation but less snow and shorter snow-covered periods.

Need for basic research

As it has become apparent that the physical environment is changing and affecting the growth of trees, eco-physiological research into the processes controlling the mass flows of a forest ecosystem has been increasing interest during the last two decades. Research based on intensive empirical work in connection with theoretical analysis aims to understand the growth of trees in terms of their interaction with the physical environment through the flows of carbon, nutrients and water. Mathematical models are used for aggregating results from the level of the physiological processes to whole trees and communities.

The rapid development of molecular biology has also opened quite new paths for forest research. For instance, the host-parasite relationship is often a chemical war with antagonistic compounds. Various kinds of genetic markers and gene mapping have been applied, in order to reveal the mechanisms of adaptation linkages between different traits. Genetic research, including gene technology, aims on the hand at finding methods to improve the productivity and quality of cultivated forests, and on the other, at clarifying the mechanisms maintaining genetic diversity.

The key issues in forest soil science today in Finland relate to the extent and rate of the possible changes in the material balance of the soil. These include soil acidification and the related leaching of base cations, excess nitrogen deposition, and the dynamics of the carbon pool in both mineral soils and peatland. In addition to the chemical processes of nutrient cycling, the role of the living organisms in the soil is focal in understanding the material balances.

Current empirical soil science focuses on the growth and turnover rates of fine roots and mycorrhiza in relation to changes in the soil chemical composition. The microbial population is perhaps the most sensitive of the biological organisms in the soil to changes in the material flows and environmental factors, reacting not only through the rates of physiological processes, but in species composition. Rates of microbial processes are fast, and the soil is very heterogeneous, so that normal sampling methods are often inadequate. The development of an empirical methodology is therefore one of the key issues in soil microbiology today.

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**Are the forests of Lapland dying?**

The extremely high emissions of sulphur dioxide and heavy metals and severe environmental destruction in the Kola Peninsula first came to Finland's attention at the end of the 1980's. A connection between these emissions and the extensive needle-loss outbreak in Lapland and forest damage in Salla, eastern Lapland, at the same time were immediately suspected. A multidisciplinary research programme, the Lapland Forest Damage Project, was established to investigate these problems.

During 1990-94 50 researchers from four universities and five state research institutes in Finland investigated the effects of industrial emissions from the Kola Peninsula on forest ecosystems in Lapland. All the studies were concentrated on a series of joint sampling and monitoring plots located along the running Finnish Lapland to the NW, W and SW from both Nikel and Monchegorsk.

Considerable amounts of sulphur dioxide and heavy metals from the Kola Peninsula are carried into the NE corner and other parts of eastern Lapland by easterly and north-easterly winds (Fig. 1). However, the duration of these high pollution episodes is short and the annual mean sulphur dioxide concentration in Lapland is relatively low.

The project has not been able to demonstrate any direct connection between the cases of tree damage reported at the end of the 1980's in Finnish Lapland and emissions from the Kola Peninsula. Visible signs of damage caused by emissions from the Ni-Cu smelters at Nikel and Monchegorsk extend for a distance of 40-50 km to the west of the point emission sources. However, sensitive bioindicators such as epiphytic lichens and the sulphur and acid rain damage symptoms in pine needles, indicate that the emissions are having an effect in Finnish Lapland.

The forest death area and visible and non-visible zones around the point emission sources in the Kola Peninsula are shown in Fig. 2. The delineation of the individual zones is based on the results of the Lapland Forest Damage Project and on mean atmospheric sulphur dioxide concentrations calculated using the Russian-Finnish sulphur dioxide distribution model.

Box: Eero Tikkanen

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**Figure 1. Atmospheric SO2 concentrations at Savettjärvi, NE Lapland, in 1982. Source: Aki Viikinko et al., Finnish Meteorological Institute. Layout: Risto Halkkarinen, Finnish Forest Research Institute**

**Figure 2. Visible and non-visible damage zones around the point emission sources in the Kola Peninsula. Source: The Eastern Lapland Forest Damage Project, Finnish Forest Research Institute. Layout: Aarn Jothikka**
Environmental concern has high priority in research organizations

The effects of forestry on water ecosystems are among the research priorities in the Finnish Environment Agency and the Finnish Forest Research Institute. Several university institutes in a close collaboration are studying the effects of forestry operations on the water ecosystems with special emphasis on how these effects are related to climatic, edaphic and hydrological conditions and how the intensity of operations and the size of the catchment area affect the recipient lakes and rivers. The effects of forests and forestry operations on balancing the water flow and the dynamics of the aquatic systems are also among the main concerns in these studies.

The effects of air pollutants on the functioning and structure of forest and mire ecosystems were widely studied in the middle of 1980s in the Finnish Forest Research Institute, the Finnish Meteorological Institute and Research Institute for Waters in close collaboration with several university institutes. The effects of air borne impurities on the forests are being monitored as a part of European collaboration in the context of the Finnish National Forest Inventory.

As the global climate change could have profound effects on the dynamics of the forest ecosystems and consequently on forestry in Finland, the future forest production is among the main concerns in the Finnish Climate Change Research Programme (Silmiu) launched for the years 1990-1995. This multidisciplinary study project is a joint effort by several governmental research agencies and university institutes throughout the country. The work in SILMU is carried out in four subprogrammes: Atmosphere, Waters, Terrestrial Ecosystems and Integration & Human Interactions. Forestry-related projects in the SILMU programme study carbon in boreal coniferous forest soil, acclimatization of tree function and structure to climate change and implications for forest carbon balance, physiological and genetical adaptation of forest trees to climatic change, and the response of the boreal forest ecosystem to changing climate and its silvicultural implications. In addition, special emphasis is given to the behaviour of mire ecosystems in a changing climate.

Managing the Forests in the Changing World: management-oriented forest research in Finland

New challenges

The last ten years have given rise to new challenges for forest management. The growth has been bigger than removals for two decades, environmental concerns have become more important, the structure of forest ownership as well as the industry has dramatically changed. Mechanization of forest operations has proceeded rapidly due to innovations in harvesting technology. This implies changes in information needs from research

Towards information intensive forestry

The planning of forestry and the forest industries needs information on the condition of forests, forest resources, growth, alternative future developments, etc. The information is based on forest inventories. There are two main forest inventory systems in Finland: the National Forest Inventory (NFI) and stand-level forest inventories.

Stand-level forest inventories are carried out separately for private, state and company-owned forests. Traditionally, aerial false-colour photographs and visual field assessment methods have been applied. The information has been used for operative forest management planning, such as the planning of cuttings and silvicultural and other improvement works. Inventories are repeated at intervals of about 10 to 15 years. Large area estimates are not necessarily unbiased.

One of the central questions in SILMU-project has been how strong carbon sink mires are.

MELA - Growth simulator for management purposes

Yield prediction remains a central question to wood production research. The growth and yield tables of the early years of forestry, based on tabulating empirical measurements from classified stands still provide a valuable source of information. However, the limitations set by their static character with respect to environment and management were realised as early as the 1960s, when the development of management-oriented growth and yield models began in Finland. The growth simulator, MELA, was introduced to national use in the 1970's and covered the whole forestry practice by the end of the decade. A growth simulator should ideally predict the growth and development of any given stand. The current development of MELA is being extended to cover not only traditionally-managed stands, but also stands with minimal or no intervention. Some of the key issues in the development of management models are the early development of a mixed stand of seedlings, the growth and structure of tree crowns, tree mortality, the development of timber quality under different conditions, tree rot, diseases, mixed forests and peatland forests, as well as stands with stratified or continuous age distribution.

The models developed by wood production scientists are largely based on empirical observation, which is indeed important for a model aiming for generality at the national level. The disadvantage of this approach is that changes in the environment will reduce the reliability of the predictions. In order to calibrate predictions with environmental change, work is underway on the variation and possible trends in tree growth.
The traditional role of the National Forest Inventory, the other inventory system, has been to provide unbiased, reliable large area forest resource information. The information has been utilized in large area forest management planning, such as determining the level of cuttings and other interventions needed as the information basis for official forest policy in the strategic planning of forest industries and, more recently, for calibrating the level of estimates of standwise inventories. The first NFI was carried out in 1921 - 1924 at the eight in 1966-94.

Line transect sampling, systematic cluster sampling and, in North Finland, two-phase stratified sampling with aerial photos and ground sample plots have been employed. The recent method exploits satellite image data (Landsat TM) and digital map data in addition to the ground measurements.

The most serious problem in the application of this method are the clouds which often prevent obtaining images of a target area from a specific year. Therefore, a study to developing methods of utilizing of ERS-1 SAR data (radar data) in large area inventories has been started. The use of other remote sensing data such as airborne scatterometer and imaging spectrometer data is also being developed.

The National Forest Inventory has traditionally produced information about biodiversity. Many research projects for introducing theoretical concepts and measures for assessing biodiversity, its development and factors affecting it have been started recently as a co-project with the Finnish Forest Research Institute and universities.

A broad ongoing research project at Helsinki and Joensuu universities is concentrated on developing methods both for small and large-scale forest inventory and monitoring systems with multisource data such as field measurements, digital aerial photographs, satellite images and other digital geo-referenced data. The goal is to develop modern resource monitoring and management systems. Among other research topics, modelling of the stem curve, the increment of diameter and height of single trees as well as timber quality can be mentioned. The multisource inventory method developed by the Finnish Forest Research Institute has been tested and negotiations about its application are going on also in countries such as Sweden, Germany, New Zealand, and China. A future goal in forest inventory research is to develop an inventory system that could combine both large and small-scale inventories.

**Efficient technologies are environmentally friendly**

In modern forest management, the efficient usage of raw materials helps to cut down operational costs. At the same time the negative effects that follow from wasteful use of natural resources are minimized. The quality of both the operations and the raw material is a guiding principle for forest management. It also sets strict requirements for research in this field.

The quality of the whole production chain from stump to final product has increasingly become the key issue. Studies concentrate on the individual aspects of the utilization of resources as well as the whole chain. Expert systems and artificial intelligence are applied to develop environmentally sound operations and compatible planning systems. Operations research methods are used at the moment in evaluating effective production alternatives. The answers to questions such as what are the key factors and what kind of measurements are needed to maximize the usage of raw material along the production chain are continuously sought. This naturally has direct linkages with the information needs of management inventories.
Individual forest operations are also undergoing rapid development. Customer-oriented wood procurement is being developed for the forest industry companies. The biodiversity considerations will affect the way harvesting planning is done in the future. Finding a satisfactory solution is crucial for ecologically sustainable forestry and the availability of wood and it is also directly linked to finding the appropriate mechanization for the changing forest sector. Apart from traditional forestry the use of wood for energy production is another key issue which has particular requirements in the production chain.

Finally, the quality of operations cannot be discussed without considering the human factor. Along with development of more efficient systems continuous studies are being carried out to consider the ergonomics of the new methods and working environment.

There are nine different institutions or bodies directly involved in forest technology related research (the main institutions are presented in the box). The major part of these studies can be classified as applied. The institutions co-ordinate their activities at research program level so that excessive overlap can be avoided. Joint research projects are designed and carried out. While research institutes are more directly concerned with the practical operations, universities have more opportunities to approach the same questions from a more theoretical point of view.

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Research on forest management techniques in Finland

University of Helsinki, Department of Forest Management in the faculty of Agriculture and Forestry:
The main study area is the quality of both the operations and the raw material.
The main methods consist of development of expert systems, artificial intelligence and operations research methods.

University of Joensuu, the Faculty of Forestry:
The main areas of interest are planning systems and optimization of harvesting, wood procurement, work studies, ergonomics and the environmental effects of mechanized forest operations.

The Finnish Forest Research Institute:
The emphasis is on proper mechanization for the changing forest sector, the use of wood for energy production and wood procurement organisation.
Methods consist of large field trials and monitoring complemented by modern theoretical tools.

Metsäteho, R&D department for timber procurement and production at the Finnish Forest Industries Federation:
Interest areas are customer-oriented wood procurement developed for the forest industry companies, the biodiversity considerations in harvesting planning, the quality of industrial forestry operations.
Main methods are field trials, system studies, product improvement, traditional R&D tools.

The TTS Institute:
Research is directed to the harvesting systems, work methods and the safety of self-employed forest owners. The other major area is the utilization of domestic wood fuels in farms and private housing.
Research methods consist of trials, in situ work monitoring, farming system studies.

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New technology considers the remainder a better way (a view from Timberjack 870)
Forestry for People: economically-oriented forest research in Finland

Forestry has a key role in national and private economies

Forest economics research can be divided into three main sectors: national and social economics of forestry, business economics of forestry and forest products marketing. The purpose of forest economics research is to support national policies in obtaining the desired mix of timber and other benefits from the forests. The most important policy sector is forest policy, but there are many other policy sectors where forests and forestry have an important role. In Finland, where forests are so essential for the national economy and the environment, forest economics research is expected to yield important input for economic, industrial, commercial, social, regional and environmental policies.

The research is dominated by three basic facts:
- timber resources have increased and they continue to increase, allowing for continued economic development based on timber resources,
- many non-timber benefits, especially ecological, recreation, landscape and cultural benefits, have gained in importance and must be given increased attention,
- Finnish forestry is dominated by small-scale family ownership, so that research on non-industrial private forest owners' values, attitudes and behavior is of particular importance for successful forest policy.

Researching the wooden base of the Finnish economy

Research in national and social economics of forestry has four main topic areas. Forest policy research describes the overall importance of the forest sector to the national and regional economies with the aid of system dynamics and economic input-output studies, identifies forest policy objectives and means and measures their coherence, as well as the effectiveness and efficiency of policy means and their environmental and income effects. Comparative forest policy research between Scandinavian and European countries provides valuable background for forest policy analysis. The long international traditions of Finnish forest research are being continued by research on the forests' role in economic development in the developing countries and the mechanisms of forest depletion. The production of forestry statistics, which is a basic tool of forest policy, is an integral part of forest policy research.

Because of the central role of private forests, research on private forest owners is manifold, covering the ownership structure and its development, and the attitudes, values and behaviour of owners. Sociological surveys and econometric models are the most currently used research methods. Not only owners, but also organizations serving private forestry like Forest Management Associations and Regional Forestry Boards are subjects of research. In order to increase forest owners' decision-making capacities and their benefits from their forests, computer-aided forest management planning tools are being developed. Other actors in the forest policy arena are also subjects of research.

Research on the social benefits of forests has concentrated mainly on employment and rural development. Since the number of forest labour is rapidly decreasing, the focus of research is turning towards rural entrepreneurship in general, covering all forest-related enterprises like timber harvesting contractors, small local sawmills and forest-based tourism.

Like the social benefits, research on the multiple use of forests has been largely carried out within the context of forest economics. Various forest uses and benefits like recreation, hunting, reindeer husbandry and landscape amenities are studied by statistical surveys and sociological analysis, and planning tools are developed in order to integrate the various benefits. The main tools undergoing development are integrated forest and landscape planning methods, public participation methods and valuation of non-timber benefits with the aid of environmental economics.

Enhancing the profitability of forestry

In business economics of forestry there are several current research disciplines. The first comprises optimization and simulation models for forest management in single tenure. The simulation model MELA is most applied currently. Planning models integrating the whole farm enterprise have also been developed.

The microeconomic profitability of forestry investments is analysed by multi-attribute utility optimization methods and by comparing predetermined investment chains. Investment analyses are carried out in regeneration and forest improvement decision problems. As a result, forest own-
ers and forest policy actors can be given advice as to the best economic choice of silvicultural and forest improvement methods. Developing accounting systems and profitability measures for non-industrial private forest owners is the third identifiable discipline. Detailed studies on forestry accounting systems are under way. Profitability estimates are developed from deflated unit costs and stumpage price indexes for example. In order to follow the development profitability over time, a system of permanent follow-up based on a sample of forest holdings keeping regular accounting is under development. It has been estimated that private owners' use of expert services also needs to be understood in order to increase private owners' benefits from the above studies. Promoting small and medium-size rural enterprises is, beside a subject of socio-economic research, also a subject of business economics research.

**Forest products need marketing research, as well**

Forest products marketing research produces information on domestic and especially export markets and explores the effect of market changes on firms' marketing and strategic planning. Because of the exceptional importance of forest industry exports to the Finnish economy, forest products marketing research has an important place among forest research disciplines.

Forest products marketing research strives to develop strategic marketing planning of forest industries, to provide up-to-date market and marketing information for the forest industries, advanced tools and models for marketing planning and implementation, and to apply marketing theories and models in the field of roundwood and forestry services marketing also. Marketing research thus covers the whole chain from the forest to the end products.

At the centre of marketing research are the development of market forecasting techniques, the development of marketing for small and medium size rural enterprises and the environmental effect of the whole life cycle of wood based products.

**Accelerating change**

Technological conditions, threats of ecological changes, social, political and economic conditions have changed the world at an accelerating tempo during recent decades. These changes bring new challenges to Finnish forest economic research.

The development of technology has had a great effect on forest management. Labour has been substituted by capital and fossil energy, and the scale of management operations has increased. The same trend has taken place in the wood-processing industries, leading to a large-scale industry. In addition, wood has been increasingly substituted by other raw materials, for example in paper-making.

Ecological changes and their threats have had an indirect influence by changing political behaviour. Forecasts of the effects of climate and other environment changes on the forests give very variable and speculative impressions of the future. In order to reduce uncertainty, biodiversity and sustainability requirements are given a very high priority in Finnish forest policy.

Technological development and nature conservation have had a social impact by changing the industrial and community structures. Rural depopulation decreases the availability of labour for forest management. The demand for non-timber forest benefits has increased because of urbanization and increased environmental awareness.

The political and economic integration and environmental movements are the main political factors changing the circumstances of forest production. The increased mobility of resources and recycling have made it possible to make good use of large-scale technology and to locate the production units profitably in relation to input and output markets.

The demand for Finnish forest industry products is very dependent on economic development in the international markets. Economic recessions have caused difficulties for the Finnish forest sector and the whole economy. In the 1990s the predictability of international economic development has decreased, which causes new problems of adjustment and a new kind of uncertainty for forest-based business.

Research into the marketing of forest products will show interest in socially responsible marketing methods which take into account the interests of producers, consumers, authorities and other interest groups and interactive relations between them. Research into comparative advantages and disadvantages of Finnish forest-based products is of importance to find out the competitive position of the Finnish forest sector in the international context. That knowledge is needed to forecast international material flows, finance flows, etc. for decision-making on investments in forestry and the wood-processing industry.
There is no Forestry without Wood-Based Products: research in wood science in Finland

Forests are the source of wealth for Finns

Forests have always had a central position for Finnish society. Before the Second World War over three-fourths of our foreign income came from trade in forest-based products. Since those days Finland has become economically more versatile but forest industries are still crucial to Finland's economic success. Forestry has become our speciality; we are among the few countries in the world whose foreign trade in forest products exceeds many times domestic consumption. The figure below illustrates the situation quite well.

![Graph showing Finland's proportion of the World's forest resources, industrial outputs, and trade of forest products.](image)

Striving for high quality

Development of Finnish society after the Second World War, the liberalization of foreign trade and increasing economic unification in the world have also driven the Finnish forest industry to change its structure. Our competitive edge in the world market must be based on high quality products and extensive know-how in manufacturing.

Development in the Finnish forest industry has been from the simple mechanical wood processing to more demanding pulp and paper industry and within the latter group from low-quality paper grades to more demanding information papers. The capacities of individual paper and board machines have almost quadrupled, being the highest in the world at the moment. The value of the forest industry production has increased but the wood consumption decreased. The same unit of production needs only a half the wood fiber required earlier.

A basic requirement for the observed development has laid in the active R&D that has been going on in Finland. This research covers the whole field from the studies on the quality of raw material to the marketing of the final product. The competing industrial companies figured out at an early phase that cooperation to solidify the national know-how in the field is to everybody's benefit. The forest industry established the internationally recognized Finnish Pulp and Paper Research Institute (KCL) to carry out process and product research in pulping and paper making but also research in the related environmental questions.

Various universities of the country have been directing their efforts to solving problems encountered in the wood products industry and in the pulp and paper industry since the beginning of this century. A department specializing in the forest products technology was established at the Helsinki University of Technology early 1940's. Cooperation between universities and KCL took a new step forward when a new Paper Science Centre attached to KCL was established.

Essential objectives in the research are the efficiency of production and the desired properties of the end product. The quality of fibres and their treatment are the main issues in developing new products. The effects of both the properties of raw material on fibre assortiment and the pulping process and used chemicals on fibre properties form an important part of the studies. Modern methods of microscopy, chemical analyzes and biotechnology are applied in combination with modelling approach and simulation studies. The chemistry and microbiology of the wet-end of paper machine need to be known if the machines are to be run faster and still maintain quality of the production. The use of recycled fibres and closing the water circulation set new challenges for research. Development of measurement technology and process control are key issues.

Research in the wood products industry is basically applied research. The focus areas in this field are improving the cooperation of small and medium-size forest product industry, more efficient use of raw materials in the production process and the utilization of wood from new
species or special trees. Emphasis is also given to increasing the use of wood for energy, control of the process of drying sawn timber and improvement of veneer production technologies and veneer products, in particular those made of conifers. Wood as construction material and special products in that field are also receiving attention.

Although the industrial companies have realized the benefits of cooperation, a great deal of R&D is still carried out in the individual companies. In the production machinery sector especially various companies have succeeded in their development work. Finnish-made paper machines are running in many mills around the world, research into pulp cooking has resulted in new environmentally friendly equipment and technologies and the Finnish companies have a leading role in developing wood-harvesting machinery.

**New products are developed from wood**

Finnish wood has numerous properties that make it good as building material. These particular properties have not always been recognized by the wood products industry. Finnish high quality wood and sawn timber is for the most part processed further abroad, although the vicinity of the raw material would offer opportunities for this in Finland.

Although Finnish nature is generous enough to supply us with very high quality wood it does not mean that it could not be improved. About 70% of the Finnish construction products exported are wood products, mainly sawn timber and boards. However, the forest resources of Finland would allow a considerable increase in these exports. From the national point of view it would pay off to process these products more, which would increase the value of exports from mere raw material to high-tech building material.

Wood is a natural renewable material which gives it a clear competitive edge in the present world. Its natural properties can also cause problems in technical use. Wood properties vary. Wood is sensitive to moisture, and biological agents decompose it. The ingenious research program in the Technical Research Centre of Finland have put aside “natural wood” and started to improve it to meet society’s new needs. By doing this they have managed to introduce new, wood-based materials that can revolutionize the use of wood in the future.

**Environmentally friendly production is a challenge for forest industries**

Forest industries markedly affect the Finnish environment. The land of forests and lakes is directly influenced by the usage of wood and through the waste generated in the production process. No wonder that a lot of emphasis has been given to solving the environmental problems associated with pulping and paper-making.

Through consistent improvements in production technology the forest industry has been able to answer the call for cleaner production. Although the volume of production has increased from the 70s for example, the biological oxygen demand has decreased so that the objective of one-tenth of the level at 1970 had already been reached at the beginning of the 1990s. The chlorine compounds have been considered especially problematic, since they are accumulated in the ecosystems. The decrease in their emissions has been a major aim of the environmental policy of the chemical forest industry. Through changes in the bleaching processes that use oxygen or ozone technologies for example instead of chlorine compounds and biological treatment of waste water it is possible to decrease the amount of lost chlorine compounds to a very low level. The use of...
Forest industry is cutting down the waste emissions

<table>
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<th>Emissions at 1993</th>
<th>National Objective level for Environmental Protection</th>
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<td>SO2</td>
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<td>1988</td>
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</table>

BOD = biological oxygen demand
AOX = absorbable, organically bounded haloene

Source: The Finnish Forest Industries Federation

Wood is an important, renewable source of energy

Bioenergy still plays a significant part in Finland's energy production. Of the annual energy consumption of 31 million toe in 1993 the share of wood-derived fuels was about 16% (5 million toe) and fuel peat about 5% (1.5 million toe). In contrast to earlier days, more than half of the wood-derived fuels is waste liquor from the pulp industry and most of the other half consists of bark and waste wood from industry. Fuel peat is used mainly in municipal heat and energy production (60%), in industry (30%) and in power production in condensing power plants (10%).

Wood offers an unused potential in energy production that has many positive side-effects. Greater use of wood fuels, as well as other biofuels, will limit CO₂ emissions originating from the use of fossil fuels. The potential increase in harvesting small-sized trees or tree sections from young stands for energy production will promote first thinnings and good silviculture. Among other benefits the contribution of new energy technology to export marketing may be mentioned. Even now the value of energy technology exports exceeds the costs of energy import in Finland.

The annual biomass production would be more than enough to support wider use of bioenergy. At present the estimated annual growth of stem wood is about 80 million m³ whereas the cuttings are at the level of 50-60 million m³. It is not obvious that potential expansions of forest industry will change this surplus. In addition, the non-commercial parts of the tree are mostly left in the forest after logging. Areas suitable for the production of peat fuel amount to about 13 times the annual energy consumption at the present level. Compared to current use the peat resources will last for centuries. The production of biofuels can also be increased by exploiting municipal wastes and using fallow for growing energy crops.

The Ministry of Trade and Industry has promoted research in bioenergy utilization in industry and in the universities and research centres. Two programmes for promoting fuel peat production were started in 1988. The new five-year program of the Ministry of Trade and Industry in energy utilization R&D for the years 1993-1998 included the Bioenergy Research Programme. The objective of this program is to improve the competitiveness of peat fuel and wood-derived fuels, as well as to develop equipment and methods that would lead to a greater use of biofuels and environmentally sound energy solutions. The main research areas are the production of wood-derived fuels, fuel peat production, the use of bioenergy, and conversion of biomass.

In the area of integrated harvesting new harvesting methods as well as processing methods for small-sized trees are being developed. The target is to find new production methods for pulp
chips that allow harvesting of undelimbed trees or tree sections with acceptable total economy. For logging of undelimbed trees new equipment and machinery is under construction. Research and development work in the harvesting of logging waste is focused on forwarding and rational means of combining transport and comminution of residues. Special emphasis is paid to the potential nutrient depletion the cutting residual harvesting might cause in the forests in the long run. Machinery for handling this biomass have been developed and the burning technology has also been extensively studied.

Abandoned agricultural land offers a potential resource for intensive rotation forestry for energy production. The fundamentals of this production has been studied since the 1970s using e.g. willow species and the scientific bases exist to start expanding energywood production on intensively cultivated short rotation fields.

**Wood is becoming an attractive option for builders**

The Finnish country-side is characterized by the wooden houses of small-scale farms. The oldest log houses date back to the 17th century. As wood has been the only feasible construction material for a long time it has maintained its popularity even at present. Numerous house factories make ready-to-erect wooden houses and the famous log-cottages are the favourite of the Finnish summer camps.

Although wood has been extensively used for house-building its use in the construction of bigger buildings has been limited. Strict fire regulations have quite efficiently hindered its use in bigger construction projects. The new “environmentally concerned” thinking has begun to make wood more attractive as a renewable natural construction material. Good experiences from North America have encouraged the wider use of wood. A lot of effort has been given to improving the fire resistance of wooden construction materials. Various research projects have also been started to assist in the design of wooden constructions.

*Wooden houses are an integral part of Finnish country side.*
Higher Education in Forest and Wood Sciences:

Faculty of Agriculture and Forestry
University of Helsinki

The Faculty of Agriculture and Forestry of the University of Helsinki conducts research and gives academic education in the sustainable use of natural resources. Over 30 subjects are taught in the Faculty's 12 departments. Three out of 12 departments are exclusively for forestry training and research and four others deal with forestry-related sciences.

Departments in Forest House:
Address: P.O. Box 24, 00014 University of Helsinki, Finland
Street Address: Unioninkatu 40B
Tel. +358-0-1911, Fax +358-0-191 7755

Department of Forest Ecology
Tropical House, Tel +358-0-70851, Fax + 358-0-708 5646

Department of Forest Economics
Department of Forest Resources Management

Disciplines: forest biology, forest soil science, peatland forestry, silviculture, tropical forestry, business economics of forestry, forest products marketing, social economics of forestry, forest mensuration, forest technology, wood science

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Address: P.O. Box 27, 00014 University of Helsinki, Finland
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Department of Plant Biology
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Department of Limnology and Environmental Protection
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Department of Applied Zoology
Fax +358-0-708 5463

Department of Economics and Management
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Disciplines: Botany, plant biotechnology, forest tree breeding, forest pathology, environmental protection, forest zoology, game science, land use economics, extension education, private forestry.

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In thirteen years the Faculty of Forestry has established a sound basis and centre for forest sciences in Joensuu. The faculty is doing research and giving academic education with the staff of 10 professors and 50 other academic researchers. There are 200 students and 70 post-graduate students annually. 35 new students are accepted. In 1994 and 1995, the Forest Ecology Research Project of Prof. Seppo Kellomäki was awarded the distinction of being a “centre of excellence in research” by the Academy of Finland. Today the Faculty of Forestry is participating in five projects in different EU research programmes and coordinating internationally a project of the AIR programme.

Disciplines:
- Environmental management of Forests
- Forest Management and Economics
- Forest Technology and Wood Industry

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Helsinki University of Technology

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Helsinki University of Technology (HUT) is the largest and oldest university of technology in Finland. It was granted university status in 1908. The University employs 102 professors, 56 associate professors, and some 1700 other teaching and research staff. The undergraduate students number over 10,000, and postgraduate students a good 2000. Some 18% of all students are women.

Laboratories:
Laboratory of Forest Products Technology
Address: Vuorimiehentie 1 A, FIN-02150 Espoo, Finland
Tel. +358-0-451 4216, Fax +358-0-451 4259
Laboratory of Paper Technology
Address: Vuorimiehentie 1 A, FIN-02150 Espoo, Finland
Tel. +358-0-451 4216, Fax +358-0-451 4259
Laboratory of Pulping Technology
Address: Vuorimiehentie 1 A, FIN-02150 Espoo, Finland
Tel. +358-0-451 4201, Fax +358-0-451 4249
Laboratory of Forest Products Technology
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Address: Vuorimiehentie 1 A, FIN-02150 Espoo, Finland
Tel. +358-0-451 4246, Fax +358-0-451 4259
Laboratory of Wood Technology
Address: Puuminenkatu 2 B, FIN-02150 Espoo, Finland
Tel. +358-0-451 4261, Fax +358-0-451 4277

Disciplines related to forest and wood science:
Pulping science and technology, paper science and technology, chemistry of the pulping and paper-making, process and production control in the pulp and paper industry, processes and materials in printed communication, wood science, wood technology.

Lappeenranta University of Technology
P.O. Box 20, 53851 Lappeenranta, Finland
Tel. +358-53-62 111
Fax +358-53-621 2350

Lappeenranta University of Technology is oriented towards the forest industry. This is evident in the teaching and research programmes in all departments. There are between 2,500 and 3,000 students studying at LUT. Every year, over 200 students obtain first degrees or postgraduate degrees in technology. The first students obtained degrees in economics in 1995.

Departments:
Business Administration
Fax 358-53-621 2640
Chemical Technology
Fax 358-53-621 2199
Energy Technology
Fax 358-53-621 2799
Industrial Engineering and Management
Fax 358-53-621 2699
Information Technology
Fax 358-53-621 2899
Mechanical Engineering
Fax 358-53-621 2499

Disciplines related to forest and wood science:
Energy systems and environmental control in the pulp and paper industry, separation technology in the pulp and paper industry, mechanical wood processing, machine and process automation in mechanical wood industry, wood cutting tool technology, FMS in wood working industry.

Åbo Akademi
Faculty of Chemical Engineering
Piispankatu 10,
20500 Turku, Finland
Tel. +358-21-265 4415

The faculty gives training for pulp and paper-making, pharmaceuticals, the oil and plastics industries. The broad range of courses and specializations offers given students great freedom of choice. By coordinating research technology with pulp and paper-making, applied chemistry, data technology, technical physics, and industrial economics, it is possible to produce engineers for many different tasks in industry. Pulp and paper-making is a strong field at the University, specializing in such fields as coating techniques and the chemistry of forest products.

Laboratories:
Laboratory of Pulping Technology
Fax 358-21-251 6757
Laboratory of Paper Chemistry
Fax 358-21-251 6757
Laboratory of Forest Products Chemistry
Fax 358-21-265 4868

Disciplines related to forest and wood science:
Pulping science, paper science, chemistry of pulping and paper-making.

Other Universities where forest-related research is done:

Helsinki School of Economics and Business Administration
Runeberginkatu 14-16, 00100 Helsinki, Finland
Tel. +358-0-431 31, Fax +358-0-431 3217

Tampere University of Technology
P.O. Box 527, 33101 Tampere, Finland
Tel. +358-31-162 111, Fax +358-31-162 170

University of Jyväskylä
P.O. Box 35, 40351 Jyväskylä, Finland
Tel. +358-41-601 211, Fax +358-41-601 021

University of Kuopio
P.O. Box 1627, 70211 Kuopio, Finland
Tel. +358-71-162 211, Fax +358-71-162 131

University of Oulu
P.O. Box 191, 90101 Oulu, Finland
Tel. +358-81-553 4011, Fax +358-81-371 158

University of Turku
20500 Turku, Finland
+358-21-633 51, Fax +358-21-331 167
**Major Research Organizations:**

**Finnish Forest Research Institute METLA**

Unioninkatu 40 A
FIN-00170 Helsinki, Finland
Tel. +358 0 857051 (switch), Fax. +358 0 625308, Telex 121286 metla sf; Internet: metla@metla.fi.
Search E-mail addresses: In most cases the form FirstName.LastName@metla.fi is applicable.

**METLA:**

A state research organization established in 1917. It is subordinated to the Ministry of Agriculture and Forestry. METLA is Finland’s central forest research organization, with the duty of furnishing research results for use by forest policy decision-makers, those engaged in forestry and the forest industry, and Finns utilizing the forests in various ways. METLA is a Member of IUFRO.

**Organization:**
The personnel of METLA is 800, of whom 225 are research officers. METLA has 2 research centres and 8 research stations. The headquarters are located in the Greater Helsinki area (Helsinki and Vantaa). Metla has 140,000 ha of research forests, of which 60,000 ha are in nature conservation areas.

**General Tasks:**
Research, national and international co-operation, technology transfer, commissioned research, service duties, management of research and conservation areas

**Public Service Duties:**
National forest inventory, forest statistics, forest taxation, inspection of pesticides, registration of regeneration stock

**Research Projects:**
The research is organized into problem-based projects, with a responsible leader. The projects are evaluated at least once in three years. In 1994 there were over one hundred projects.

**Main sectors of current research:**
Underutilization of timber resources, biodiversity in forests, forest health, multiple-use of forests, forest inventory methods, forest regeneration, structural changes in private forestry, environmental effects of forestry, afforestation of abandoned fields

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**The Finnish Pulp and Paper Research Institute (KCL)**

P.O. Box 70, FIN-02151 Espoo, Finland
Street address: Tekniikanlantie 2, Otaniemi, Espoo
Tel. +358-0-43711, Fax. +358-0-464 305, Telex 1001522 KCL.fi

**KCL:**
Research institute for the pulp and paper industry. The institute carries out goal oriented basic research and precompetitive R&D work for the pulp and paper industry financing KCL, contract work for pulp and paper & affiliated industries worldwide

**Main sectors of Research:**
Mechanical and chemical pulping, bleaching, paper and board coating, additives, wood and fibre chemistry & physics, analytical chemistry, process technology & control, printing environmental studies, testing services.

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**The Foundation for Forest Tree Breeding**

Viljatie 4 A 5
SF-00700 Helsinki, Finland
Tel. +358-0-359 022, Fax +358-0-359 720

**Haapastonsuojja Tree Breeding Centre:**
Karkkilantie 247
12600 Läyläinen
Tel. +358-14-443 260, Fax +358-14-443 030

**The Foundation for Forest Tree Breeding:**
A development organization whose main objective is practical tree breeding in Finland. In addition to that the Foundation develops breeding and seed production techniques. The activities of the Foundation are mainly state funded. Plant production is nowadays separated into another organization called Taimikolmio.

**Main research areas:**
Seed orchard development, micropropagation of broad-leaved trees, controlled seed production methods and improvement of regeneration stock for Northern Finland.

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**Metsäteho, The R&D Department for Timber Procurement and Production at the Finnish Forest Industries Federation**

P.O. Box 194
SF-00130 Helsinki, Finland
Street Address: Fabianinkatu 9 B
Tel. +358-0-132 521, Fax +358-0-659 202

**Metsäteho:**
Private research institute financed by the Finnish Forest Industries Federation (FFIF), The Finnish Forest and Park Service and the Private Forestry Employers Association (PFEA).

**Main research sectors:**
Forest regeneration practices, thinning options, forest environment management, mechanisation in silviculture, timber harvesting, transport and measuring methods and equipment, properties of wood raw material, product-based control of wood flow, organization and quality of wood work.
VTT, Technical Research Centre of Finland
P.O. Box 1000, Vierumiehentie 5, Espoo
FIN-02044 VTT
Finland
Tel. +358 0 456 6741, Fax +358 0 456 7011.

VTT: The largest independent contract research centre for industry and the public sector in the Nordic countries, employing 2,600 persons. VTT conducts research in electronics, information technology, automation, chemical technology, biotechnology and food research, energy, manufacturing, building and community development.

Main Departments for research in forest and wood sciences:

**VTT-Energy**
P.O. Box 1603, 40101 Jyväskylä, Finland.
Tel. +358-41-672 611, Fax +358-41-672-597

**VTT Construction Technology and Wood Technology**
P.O. Box 1806, 02204 VTT, Finland
Street address: Puuamienkatu 2A, Espoo.
Tel. +358-0-456, Fax +358-0-456 7027

**VTT Space Technology, Laboratory of Remote Sensing**
P.O. Box 13031, 02204 VTT, Finland
Street address: Metallimiehenkatu 10, Espoo.
Tel. +358-0-456, Fax +358-0-456 4496

Main research sectors in forest and wood sciences:
Wood products, wood material technology, wood products production processes, wood structures, wood technology, bio-energy, remote sensing

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**The TTS-Institute, Työtehoseura**
P.O. Box 28,
FIN-00210 Helsinki, Finland
Street address: Melkonkatu 16 A
Tel. +358-0-692 2445, Fax. +358-0-692 2084
E-mail: tis-forest@helsinki.fi

**TTS-Institute:**
A non-profit research, development and adult education institute serving agriculture, forestry, home economics and associated fields.

Main research sectors in the forestry department:
Forest work methods of private forest owners, utilization of fuelwood and peat on farms, design and construction of forest machines.

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**Agricultural Research Centre**
31600 Jokioinen, Finland
Tel. +358-16-1881, Fax +358-16 188 22

**Finnish Environment Agency**
Kesäkatu 6, 00260 Helsinki, P.O. Box 140, 00251 Helsinki
Tel.+358-0-403 000, Fax +358-0-4030 0190

**The Finnish Game and Fisheries Research Institute**
P.O. Box 202,
00151 Helsinki, Finland
Tel. +358-0-228 811, Fax +358-0-628 396

**Finnish Wood Research Inc.**
P.O. Box 367,
02151 Espoo, Finland
Street address: Tekniikan t 12
Tel. +358-0-4354 2022, Fax 4354 2200

**International Research Organizations:**

**The European Forest Institute (EFI)**
Torikatu 34,
80100 Joensuu, Finland
Tel. +358-73-252 020, Fax +358-73-124 393
Email template to all personnel is firstname.lastname@efi.joensuu.fi. General messages should be directed to effsec@efi.joensuu.fi.

EFI: an independent and non-governmental research body, conducting problem-oriented and multi-disciplinary forest research at the European level in order to serve the needs of policy-making and decision-making bodies in Europe. EFI undertakes research on: forest policy, including its environmental aspects, the ecology, multiple use, resources and health of European forests, the supply of and demand for timber and other forest products, forecasts for the future development of European forest resources and their utilization.

**Main activities:**
Provides relevant information for policy-making and decision-making in European countries relating to the forest and forest industry sector, conducts research in the above mentioned fields, develops research methods, compiles and maintains data concerning European forests organizes and participates in scientific meetings, organizes and participates in forest research training, publishes and disseminates knowledge of its work and results.
Supporting and associated organizations and scientific societies:

The Academy of Finland
P.O. Box 57,
00551 Helsinki, Finland
Street address: Hämeentie 68
Tel. +358-0-774 881
Fax +358-0-7748 8299

The Finnish Association for Nature Conservation
Kotkankatu 9
00510 Helsinki, Finland
Tel. +358-0-228 081
Fax +358-0-2280 8200

The Finnish Forestry Association
Salomonkatu 17B,
00100 Helsinki, Finland
Tel. +358-0-694 0300
Fax +358-0-693 3466

The Finnish Forest and Park Service
P.O. Box 94,
01301 Vantaa, Finland
Street address: Vernissakatu 4
Tel. +358-0-857 841
Fax +358-0-8578 4219

The Finnish Society of Forest Science
P.O. Box 24,
00014 University of Helsinki, Finland
Street address: Unioninkatu 40 B
Tel. +358-0-658 707
Fax +358-0-191 7619

Forestry Centre Tapio
Maistraatinportti 4A
00240 Helsinki, Finland
Tel. +358-0-15 612
Fax +358-0-156 2232

The Foundation for Research of Natural Resources in Finland
Salomonkatu 17 A
00100 Helsinki, Finland.
Tel. +358-0-694 2762, Fax +358-0-694 9053

Foundation of Foresters
Ulvilantie 23B 13
00350 Helsinki, Finland
Tel. +358-0-551 584
Fax +358-0-551 584

Heureka, The Finnish Science Centre
P.O. Box 166
01301 Vantaa, Finland
Street address: Tiedepuisto 1
Tel. +358-0-857 99
Fax +358-0-873 4142

International Peat Society
Kuokkalantie 4,
40420 Jyväskylä, Finland
Tel. +358-41-674 042
Fax +358-41-677 405

Lusto, the Finnish Forest Museum and Forest Information Centre
58450 Punkaharju
Tel. +358-57-345 100
Fax +358-57-345 1050

Maj and Tor Nessling Foundation
Pohjoisrenkaankatu 3A,
00260 Helsinki, Finland
Tel. +358-0-406 616
Fax +358-0-406 684

The Ministry of Agriculture and Forestry, Department of Forest Policy
P.O. Box 232,
00171 Helsinki, Finland
Street address: Hallituskatu 3A
Tel. +358-0-1601
Fax. +358-0-160 2400

Society of Dendrology
Secretary: Stina Juhanoja M.Sca
Toivonlinnantie 518,
21500 Piikkiö, Finland.
Tel. +358-21-477 2200
Fax. +358-21-477 2299