

FOREST GENETIC RESOURCE MANAGEMENT IN FINLAND



Publishers: Finnish Forest Research Institute and Ministry of Agriculture and Forestry
Text: Mari Rusanen (mari.rusanen@metla.fi), Jaakko Napola, Teijo Nikkanen,
Matti Haapanen, Timo Herrala, Pekka Vakkari and Leena Yrjänä
Translators: Audipec and Michael Starr
Photos: Erkki Oksanen, pages 1, 17-20, Teijo Nikkanen, pages 2-17
Cover: Black alder (photo: Erkki Oksanen), golden spruce (*Picea abies f. aurea*),
Scots pine and silver birch (photos: Teijo Nikkanen)
Layout: Raili Voipio/Metla/Communications
ISBN: 951-40-1905-9
Printed in: Dark Oy, Helsinki, 2004
Copyright: Finnish Forest Research Institute

FOREST GENETIC RESOURCE MANAGEMENT IN FINLAND



CONTENTS

Introduction	2
Conservation methods for forest genetic resources	4
Genetic research	13
Tree breeding and the use of genetic resources	15
Forests and forestry in Finland	18



INTRODUCTION

Genetic diversity ensures the success of species in environments that are highly variable and subject to change. Ultimately, the genetic diversity of trees forms the basis of forestry and related forest industries. It is therefore vital that genetic resources be conserved, maintained and used in a sustainable manner to ensure the preservation of genetic diversity for future needs. Indeed, man, as steward of the earth, has an ethical responsibility to preserve species and safeguard genetic diversity for future generations.

The management of genetic diversity has been given high priority in Finland. **A National Plant Genetic Resources Programme**, covering plant genetic resources in agriculture, horticulture and forestry, was launched by the Ministry of Agriculture and Forestry to promote the conservation and sustainable use of genetic resources.* The implementation of the programme for agriculture and forestry is monitored by an advisory board, which acts as a link between various ministries, participates in the preparation of legislation concerning plant genetic resources and deals with Nordic and international issues related to plant genetic resources. The Finnish Forest Research Institute, which is responsible for all forest tree breeding in Finland, is the body responsible for the conservation of forest genetic resources.

Trees do not recognise national borders. For the good management, use and conservation of genetic resources, efficient international cooperation is required at the global, European and Nordic levels. There are several international agreements and programmes dealing with the management of genetic resources, the most important for Finland being:

Convention on Biological Diversity, CBD

The Convention on Biological Diversity was set up under the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. It aims at conserving the biodiversity and sustainable use of biological resources. Finland signed the Convention in 1994.

EUFORGEN

Resolution 2 of the first Ministerial Conference on the Protection of Forests in Europe, held in Strasbourg in 1990, obliges the signatory states to conserve their own forest genetic resources. This led to the establishment of the European Forest Genetic Resources Programme (EUFORGEN), which was adopted by the second Ministerial Conference on the Protection of Forests in Europe held in Helsinki in 1993. Activities related to EUFORGEN were initiated in 1994 and a total of 31 European countries, including Finland, are involved in the programme today.

Nordic cooperation

In 2000, the Nordic Council of Ministers decided to appoint a Nordic Genetic Resource Council, the purpose of which was to act as an advisory body to the Council of Ministers in matters concerning the genetic resources of forest trees. The Nordic Genetic Resource Council cooperates closely with the gene banks and organisations responsible for the conservation of forest genetic resources throughout the Nordic region. These organisations include the Nordic Council for Forest Reproductive Material (NSFP) and the Nordic Forest Research Cooperation Committee (SNS). Within the Nordic Network for Forest Gene Conservation, which is subordinate to the Nordic Council for Forest Reproductive Material, national experts exchange ideas and experiences related to the practical management of genetic resources.

**The aim of genetic conservation is
to secure the adaptability of populations and species
in a changing environment by maintaining
a sufficient level of genetic variability.**

CONSERVATION METHODS FOR FOREST GENETIC RESOURCES

The purpose of conserving of forest genetic resources is to maintain hereditary variation in species and local populations far into the future so that their viability and adaptability would be sufficient to cope with changing environmental conditions. Environmental change could be, for example, long-term climate change or changes in ecological conditions caused by forest treatment and management practices.

Methods for conserving forest genetic resources can be classified into two types according to whether the genetic resources are conserved at the original site - *in situ* or outside the original site - *ex situ*.

In situ conservation

normally requires that a representative area of undisturbed, natural forest or a naturally regenerated commercial forest is set aside as a gene reserve forest.

Ex situ conservation

is implemented by establishing collections of individual trees in an orchard or by storing seeds, pollen or tissue.

The principal and complementary gene conservation methods that have been adopted for each tree species in Finland are presented in Table I.



Table 1.

The methods of gene conservation for Finnish tree species. *In situ* gene reserve forests are used to conserve the common and widely distributed species while rare tree species are primarily conserved by establishing *ex situ* collections.

Tree species	Method			
	Nature conservation areas	Gene reserve forests	Collections	Breeding populations
Scots pine <i>Pinus sylvestris</i>	○	◆	○	○
Norway spruce <i>Picea abies</i>	○	◆	○	○
Juniper <i>Juniperus communis</i>	◆		○	
Silver birch <i>Betula pendula</i>	○	◆	○	○
Pubescent birch <i>Betula pubescens</i>	○	◆		
Black alder <i>Alnus glutinosa</i>	◆		○	
Grey alder <i>Alnus incana</i>	○		○	
European aspen <i>Populus tremula</i>	○		○	○
Mountain ash <i>Sorbus aucuparia</i>	○		○	
Small-leaved lime <i>Tilia cordata</i>	○	○	◆	
Common ash <i>Fraxinus excelsior</i>	○	○	◆	
Pedunculate oak <i>Quercus robur</i>	○	○	◆	
Norway maple <i>Acer platanoides</i>	○	○	◆	
Mountain elm <i>Ulmus glabra</i>	○		◆	
European white elm <i>Ulmus laevis</i>	○		◆	
Siberian larch <i>Larix sibirica</i>			○	

- ◆ Principal conservation method
- Complementary conservation method

The conservation of the genetic resources of grey alder, European aspen and mountain ash does not require intensive special measures because these species occur in large numbers in Finland, and they are also widely distributed outside commercial forests and they are not demanding in their habitat requirements.

Siberian larch is not a native species in Finland, but its distribution extends to areas adjacent to Finland. A well adapted seed source is available and its conservation must be ensured.



Genetic variation in natural populations

In natural populations, genetic variation is affected by mutation, recombination, gene flow, selection and genetic drift.



Mutation

Results in completely new gene varieties, but it occurs so seldom that it generally has little significance to the survival of individual populations.

Recombination

produces new combinations of existing genes in conjunction with sexual reproduction.

Gene flow

means the flow of genes from one forest stand to another via seeds and pollen dispersion. Effective gene flow evens out genetic differences among forest stands and increases variation within individual stands.

Selection

affects variation in traits that are important to the survival of the trees. The best trees will be most successful in reproduction, and the population, on average, will become better adapted to the local conditions. However, this will also lead to a decrease in genetic variability, which will make the population less capable of coping with environmental changes.

Genetic drift

means the random loss of alleles from populations. This loss is more probable in small than in large populations.

In situ conservation

Protected areas and habitats

The principal objective of national parks, nature reserves and other forested conservation areas is to preserve forest ecosystem, but at the same time they may serve genetic conservation. Most of the conservation areas in Finland are on state-owned land and enjoy legal protection and are meant to be permanent. Some small, special habitats, which are valuable for forest trees, are also protected by the Forest Act and the Nature Conservation Act (80/1997).

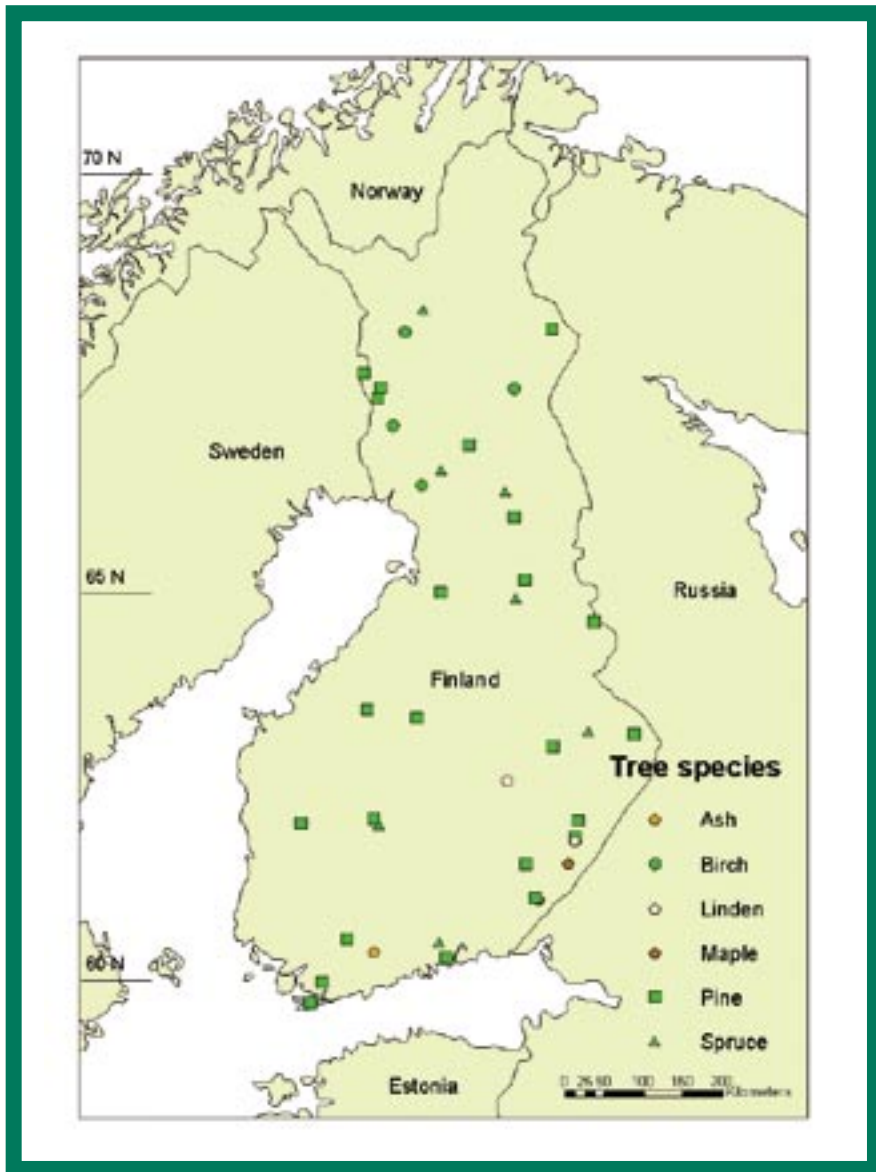
These regulations are important to the genetic conservation of certain rare tree species because, according to the Nature Conservation Act, natural woods rich in noble hardwoods or black alder and also juniper meadows can be selected as special objects whose treatment must not endanger the special features of the areas. However, for genetic conservation purposes, the nature reserves have two important limitations. Firstly, their coverage and geographic location do not correspond to the needs of genetic conservation. Secondly, the protection prevents management that would be needed to promote regeneration. The regulations also restrict the utilisation of genetic resources.

Gene reserve forests

There are 39 gene reserve forests in Finland altogether and their combined area is about 6,700 hectares. As the network of forest stands are spread over different climate zones, a large range in adaptive traits is included.

*Seed collection in
a small-leaved lime
gene reserve forest.
Seed is collected for both
conservation and research
purposes.*





The location of gene reserve forests in Finland

The principal aim has been to create an extensive network of gene reserve forests for Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), as well as for silver birch (*Betula pendula*) and pubescent birch (*Betula pubescens*). While the network of gene reserve forests for Scots pine is nearly sufficient, those for Norway spruce and the birch species are not. Both spruce and birch are frequently regenerated by planting. In addition, as much of the land is privately owned, it has proven hard to set aside land for gene reserve forests in southern Finland. To overcome these problems, mixed stands and stands that are smaller than the final goal will also be selected for gene reserve forests for Norway spruce and birch species.

Table 2.

Number and area of gene reserve forests for the main species.

Tree species	Objective		Currently (2003)	
	number	area, ha	number	area, ha
Scots pine <i>Pinus sylvestris</i>	24	5200	22	4700
Norway spruce <i>Picea abies</i>	12	2000	8	1500
Birch species <i>Betula sp.</i>	8	750	4	400
Small-leaved lime <i>Tilia cordata</i>	5	40	2	19
Maple + lime	2	15	2	15
<i>Acer plantanoides</i> + <i>Tilia cordata</i>				
Common ash <i>Fraxinus excelsior</i>	1	30	1	30

Requirements for a gene reserve forest

The basic requirements for a gene reserve forest are that it is of local origin and preferably has been naturally regenerated. Normally a stand is selected as a reserve for a certain species, but mixed species are allowed and the area should comprise several age classes. Gene reserve forests of wind-pollinated tree species, such as Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pendula* and *B. pubescens*) should be large enough for sufficient pollination to be secured within the forest. The general objective is that a gene reserve forest should cover an area of at least 100 hectares, but initially the area can be smaller if it can be expanded later using a seed source from the same stand. Since pure birch or Norway spruce forests are seldom large enough in southern Finland, suitable mixed stands consisting of two or three tree species have also been selected as joint gene resources. For noble hardwoods, which are rare and only grow in small patches, strips or mixed stands in Finland, smaller areas covering only a few hectares are accepted as gene reserve forests.

*A natural
birch stand within
Koli National Park*



Management of gene reserve forest

In order to ensure continuity, several age classes are maintained in the gene reserve forests. Natural forest regeneration is used whenever possible but otherwise normal management, including thinning and felling, is practised. When artificial regeneration is required, the seeds must come from the very same stand. To prepare for emergencies, such as storms and forest fires, seeds are collected from gene reserve forests and stored. Gene reserve forests are also used for timber production and for research. Seeds are used as reference material in forest tree breeding.



Scots pine gene reserve forest in Kerimäki, established in 1992

Ownership of gene reserve forests

The gene reserve forests are owned by the Finnish Forest and Park Service, the Finnish Forest Research Institute and some industry companies (M-Real, Stora Enso, UPM-Kymmene, Fiskars). In addition, there is currently one gene reserve forest owned by a private person.

All the owners have designated their forests for gene conservation free of charge, while retaining full ownership of the forest. The owners have made a long-term commitment to always use natural regeneration or to use reproductive material originating from the same forest. The owners are responsible for standard forest management but if artificial regeneration is needed, they are entitled to reimbursement for the extra expenses arising from seed collections and growing the plants as special lots.

Ex situ conservation

Ex situ conservation is appropriate when the tree species is rare and grows only as small patches, when the site is threatened or when regeneration is uncertain. The principal method for the *ex situ* conservation of forest tree species is the establishment of tree collections. The individual trees are either propagated by grafting and the grafts moved to clone collections or seed is collected from the original trees and so-called family collections are established with seedlings.

In family collections, several seedlings of one family are planted near each other, and thinning is carried out so that only one tree, representing the family is finally left growing. The families representing the same forest are distributed within the collection so that it can also be used for seed production after thinning. One of the benefits of tree collections is that some selection takes place within them. They produce well-adapted and genetically variable seed that can be used in forest regeneration or in landscaping.

The *ex situ* collections have been established mainly for noble hardwoods. Material for the collections has been gathered from several (20-90) forest stands, usually 5-10 trees from each stand so that the whole distribution area of the tree species is covered. The number of stands and trees per stand varies among species because the availability of seeds has directed the practical work.

The trees selected for genetic resource collections are not necessarily the best trees from the point of view of forestry and economy, as the aim has been to collect a random sample of the existing genetic variation. In general, one collection has been established for a species, only the collection of lime has been divided into a southern and northern part. The aim is to propagate all the genetic resource collections and to establish a duplicate reserve collection in another locality in the future.

Ex situ collections, such as this collection of lime, are important in the conservation of rare species.

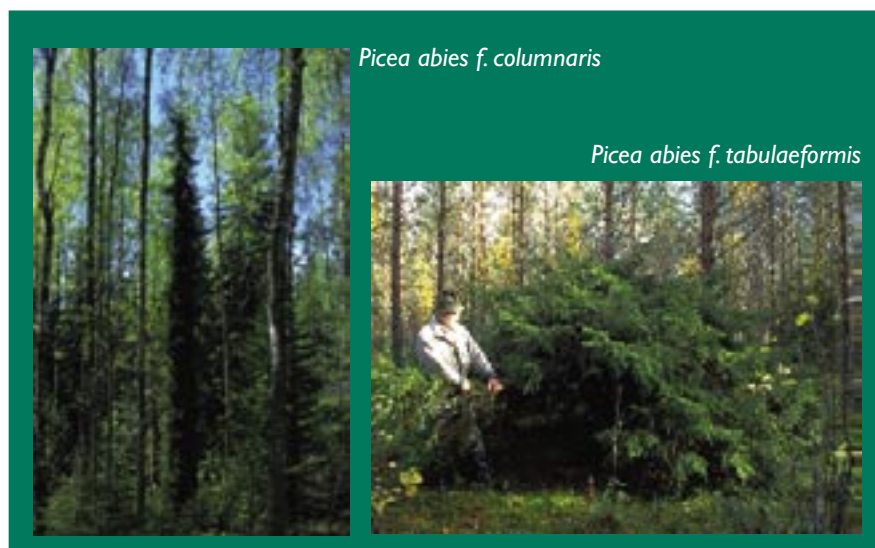


Table 3.

Collections of noble hardwood species. For practical reasons, the *ex situ* collections of lime and elms have been established by grafting, whereas for oak, maple and ash using seedlings.

Tree species	Objective		Currently (2003)	
	Forest stands	Clones/ Families	Forest stands	Clones/ Families
Norway maple <i>Acer plantanoides</i>	50	290	42	268
Common ash <i>Fraxinus excelsior</i>	20	170	29	152
Pedunculate oak <i>Quercus robur</i>	20	170	25	163
Small-leaved lime <i>Tilia cordata</i>	70	400	91	506
Mountain elm <i>Ulmus glabra</i>	40	250	38	220
European white elm <i>Ulmus laevis</i>	30	150	19	125

In nature, many tree species have special forms resulting from hereditary factors, such as golden spruce and curly birch. Deviating forms are rare and, except for curly birch, they are mainly used as ornamental trees. However, they are valuable as manifestations of variability and have thus been included in collections.



GENETIC RESEARCH

Multi-disciplinary research and cooperation between organisations is required to tackle the issues related to the conservation and sustainable use of genetic resources. In Finland, both the management of genetic resources and forest tree breeding have been assigned to the Finnish Forest Research Institute, whose duties also include forest genetics research. Finnish universities also conduct research in the field of tree genetics. The control of trade of plants and genetic resources is appointed to the Plant Production Inspection Centre, working in close cooperation with the Forest Research Institute.

Finland has a strong research tradition in the reproduction biology of wind-pollinated tree species (Scots pine, Norway spruce and silver birch) as well as the phenology of these species.



Results from research have been applied to seed management planning and seed orchard techniques. In our northern conditions, expertise in the phenology and adaptive traits of native tree species has been very necessary, and the knowledge gained has been used to provide recommendations for provenance transfers. Seed orchard research and tree breeding work have improved the quality of the regeneration material used in Finland.

Current research topics include gene flow and genetic variation in seed orchards of Scots pine and Norway spruce, the evolutionary biology and genome research of Scots pine (*Pinus sylvestris*) (University of Oulu and Finnish Forest Research Institute), silver birch (*Betula pendula*) genome research (University of Helsinki), and conservation genetics (Finnish Forest Research Institute). The research in the conservation genetics has focused mainly on problems related to small population sizes and fragmentation, particularly for noble hardwoods such as pedunculate oak (*Quercus robur*), Norway maple (*Acer platanoides*) and European white elm (*Ulmus laevis*). Results concerning the amount of genetic variation and distribution among these species have been used to design conservation collections. Another line of conservation research has focused on the cryo-preservation of the meristematic tissue of birch. The method and also that for micropropagation of birch has been mastered, but not applied in practical conservation.

Isolation bags are used for controlled crossing in a Scots pine collection



Pollen traps in a maple canopy



Cryopreservation of meristematic tissue of birch

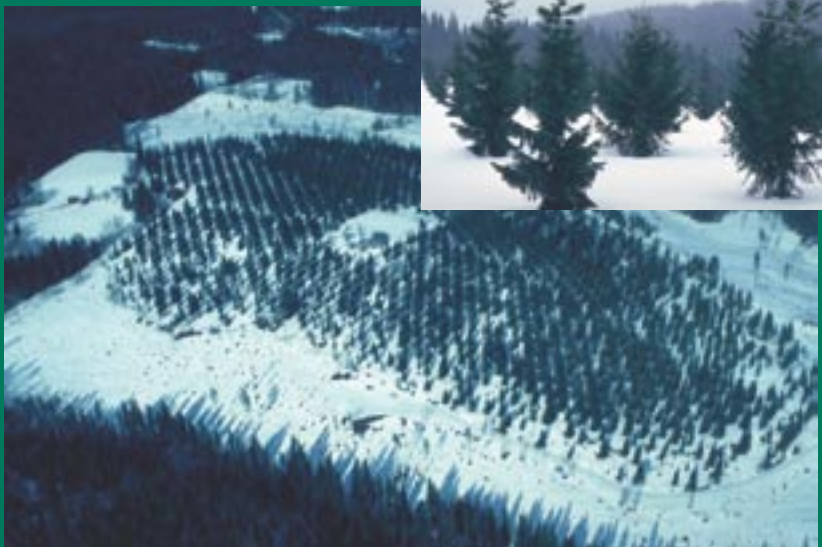
TREE BREEDING AND THE USE OF GENETIC RESOURCES

Man has affected the genetic diversity of plants for thousands of years through selective breeding and transfer of reproductive material. Cereal plant breeding has resulted in many varieties, the history of which are accurately known, genetically highly uniform and distinct from each other. Forest tree breeding is a young branch in this field and operates mostly with natural populations. And even the aim of tree breeding is usually not to create a uniform variety but rather to retain high genetic variability while improving the desired characteristics, namely growth, stem quality, fibre traits, and, especially important in a harsh climate, good adaptation.

Improved regeneration material of all three main tree species in Finland (*Pinus sylvestris*, *Picea abies* and *Betula pendula*) is produced in seed orchards. Due to climatic differences, each and every seed orchard provides regeneration material for a certain delineated utilisation area and having several breeding populations and seed orchards guarantees the availability of the seed for the whole country. The genetic diversity of the regeneration material is ensured by following the recommendations on the minimum number of clones used in any seed orchard.

A minimum number of 20 clones is currently seen needed to assure sufficient diversity of the seed crop from a seed orchard. In reality, the current Scots pine and Norway spruce orchards in Finland contain many more clones than 20.

A Norway spruce seed orchard



The genetic diversity is also increased because much of the pollen originates from outside of orchards. Hence, seed orchard lots are generally considered to contain at least as much genetic diversity as seed lots collected from wild stands.

Improved forest seeds are produced in seed orchards covering more than 2500 hectares. Nearly all Scots pine and silver birch nursery sowings and most of Norway spruce nursery sowings in southern and central Finland are done with seed orchard seed.



Around 150 million forest tree seedlings are produced yearly in Finland.

Clonal propagation of plant material is a method to achieve more rapid genetic gains than by seed production. In Finland, vegetative propagation has been mainly used in the breeding of aspen (*Populus tremula* and also a hybrid *P. tremula* x *tremuloides*), in which genotypes with specific wood fiber properties have been identified and selected. Clonal propagation is particularly appropriate for aspen because it propagates clonally in nature, and because large numbers are not required as the importance of aspen in the forestry is fairly limited. The area planted each year with clonal aspen plants has been only about 200 ha in recent years. Another species with some clonal production is curly birch (*Betula pendula* var. *carelica*). As clonal material has reduced genetic diversity compared with seed material, it is important to ensure that the clones are sufficiently resistant against the most common pathogens.

The legislation concerning the trade of forest reproductive material also covers the issue of genetic diversity. The most important regulations are Council Directive 1999/105/EC on the marketing of forest reproductive material, the Act on Trade in Forest Reproductive Material (No. 241/2002) and the decree that enforces the Act by laying regulations down, e.g., the maximum number of marketable copies from a single clone. Genetic diversity has also been taken into consideration as part of sustainable forestry at several levels of forest management, e.g., in the Forest Act and forest management guidelines. Implementation of sustainable forestry is monitored with the help of the Finnish Forest Certification System – FFCS.



*Collection of cones
in a Norway spruce
seed orchard*



Taking samples of curly birch



A juniper meadow



*Selection of hybrid aspen trees
for a trial*

FORESTS AND FORESTRY IN FINLAND

Source: Finnish Statistical Yearbook of Forestry 2003

Forest resources

- ◆ forest land: 23.1 million ha
- ◆ forest land share of total land area: 76 %

- ◆ growing stock: 2 024 million m³
- ◆ net annual increment: 81 million m³

- ◆ mean stem volume on forest land: 97 m³ ha⁻¹
- ◆ mean increment on forest land: 3.9 m³ ha⁻¹

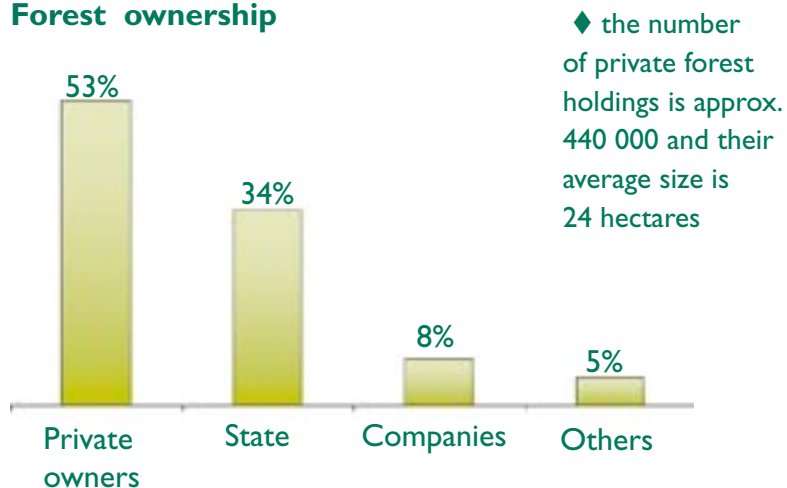
Tree species by growing stock volumes

- ◆ Scots pine 47 %
- ◆ Norway spruce 34 %
- ◆ birch 15 %
- ◆ other species 4 %

Duration of the growing season

- ◆ most of southern Finland 180 days
- ◆ most of northern Finland less than 120 days

Forest ownership



Removals

- ◆ 54 million m³ yr⁻¹
- ◆ area harvested 591 000 ha yr⁻¹
 - thinning 57 %
 - regeneration fellings 32 %
 - other fellings 11 %

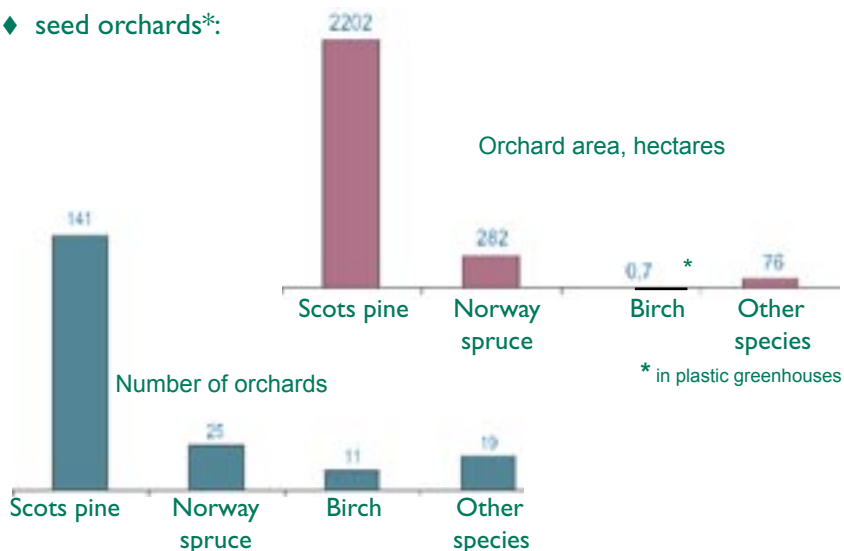
Regeneration

- ◆ annual regeneration area 158 000 ha yr⁻¹
 - natural regeneration 23 %
 - planting 56 %
 - sowing 21 %
- ◆ tree species of the regeneration area
 - Scots pine 50 %
 - Norway spruce 45 %
 - other species 5 %

- ◆ annual consumption of forest seed in artificial regeneration is approx. 12 000 kg, of which nearly 2000 kg are used in nurseries and approx. 10 000 kg in the direct sowing

- ◆ seedling production 154 million yr⁻¹
 - Norway spruce 59 %
 - Scots pine 35 %
 - other species 6 %

- ◆ seed orchards*:



*Source: General Statistics on Forest Tree Breeding in Finland 2002

Forest conservation

- ◆ strictly protected forests account for 7.2 % of the forest and scrub land area
- ◆ strictly protected forests and forests under restricted forestry use account for 12.1 % of the forest and scrub land area



Forestry and forest industries:

- ◆ forestry and forest industries account for approx. 7 % of GDP
- ◆ forest industry products account for 25 % of total export volume
- ◆ with its 8 % share, Finland is the world's third biggest export country for forest industry products

METLA

FINNISH FOREST RESEARCH INSTITUTE

Unioninkatu 40 A
FIN-00170 Helsinki
Finland
tel. +358 10 2111
www.metla.fi

Conservation of forest genetic resources is
an integral part of the conservation of biodiversity and
sustainable forest management.

This brochure introduces the objectives, methods and achievements
of the Finnish forest gene conservation strategy.

The brochure has been prepared by the Finnish Forest Research
Institute and the Ministry of Agriculture and Forestry has supported
its publication financially.



MINISTRY OF AGRICULTURE AND FORESTRY

PO Box 30
FIN-00023 Government
Finland
tel. +358 9 16001
www.mmm.fi