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Finland's forest genetic resources, use and conservation

Mari Rusanen, Egbert Beuker, Leena Yrjänä,
Matti Haapanen and Sanna Paanukoski

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Mari Rusanen, ORCID ID, https://orcid.org/0000-0002-2270-6984

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Authors: Mari Rusanen, Egbert Beuker, Leena Yrjänä, Matti Haapanen and Sanna Paanukoski
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Preface

The Food and Agriculture Organization of the United Nations (FAO) has for decades recognized the value of genetic resources in agriculture and in forestry. The first report on the State of the World's Forest Genetic Resources was agreed by the Commission on Genetic Resources for Food and Agriculture at its Fourteenth Regular Session in 2013, followed by the Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources.

Finland recognizes the role of genetic resources in sustainable forest management as well as in the ecosystem services that forests provide for people.

This publication is an edited version of the second national report on the state of forest genetic resources in Finland, that has been delivered to the FAO in June 2020, as contribution to the second report on the State of the World's Forest Genetic Resources. The official report, used jointly with the data that was submitted directly in an electronic format, is designed and written to support the global analysis. This edited version is somewhat shortened but still contains all the key information of the original report. The authors wish that the readers find the report informative and usable, making the national information available for the English-speaking readers.

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Executive summary

Mari Rusanen[1)], Egbert Beuker[1)], Leena Yrjänä[1)], Matti Haapanen[1)] and Sanna Paanukoski[2)]

[1)] Natural Resources Institute Finland (Luke)

[2)] Finnish Ministry of Agriculture and Forestry

Three fourths of the land area of Finland is covered by forests. The forest area, 22.8 million hectares, has remained almost unchanged over the last 50 years, whereas the volume of growing stock has increased by more than 40% since 1971, being now 2 473 million m^3. In the same time, the area of protected forests has tripled.

The vision of the updated National Forest Strategy 2025 is: Sustainable forest management is a source of growing welfare. The vision highlights the diverse welfare derived from forests as well as the fact that forests provide solutions to people´s and society´s needs. The forest sector is the cornerstone in the development of a sustainable and circular bioeconomy in Finland. The use of genetically improved material in forest regeneration has already significantly contributed to the increase of the annual increment of the growing stock in Finland for all three major tree species and will continue to do so also in the near future. The strategy acknowledges the importance of both the use and conservation of forest genetic resources to guarantee the genetic diversity, vitality and adaptability of tree species, in changing climatic conditions.

Finland's National Genetic Resources Programme for Agriculture, Forestry and Fishery (2018) brings together for the first time the gene conservation of plants and animals. For forest trees it lays out the need for conservation and defines the primary conservation methods (*in situ* or *ex situ*) for a total of 14 tree species, continuing the strategy that was already chosen in the previous national programme on forest genetic resources. Thus, conservation covers almost all financially or ecologically important tree species in Finland. The total number of gene reserve forests in Finland in 2020 is 44, covering an area of 7 218 ha. *Ex situ* –collections include 9 species for which material was collected from altogether 314 natural populations.

Forest genetic resources in Finland are used in a sustainable way. Around one fifth of forest regeneration is natural and four fifth artificial through planting or direct sowing. There is increasing interest in alternative forest management practises, such as continuous-cover forestry and there is a need to study the effect of this on the genetic variability. Finland has a long-term tree improvement programme for the six most important tree species. The breeding programme is managed by the Natural Resources Institute Finland (Luke) as a fully state-financed public service. Breeding goals for all species include volume production, timber quality and adaptedness to various sites and climates. Around 60–70% of the seed for reforestation is produced in seed orchards. Cold hardiness is an important trait in the harsh climate of Finland and the application of optimal deployment areas for both non-improved and improved origins of forest reproductive material is considered highly important. For the users of forest reproductive material there are new tools to assist in making the right choice of regeneration material but there is still a need to promote the use of these tools and to expand their usability to a wider selection of species. For monitoring the success and for adapting the decision support tools as well as the regulations, it is extremely important to set up a geo-referenced system that keeps records on the origin of the regeneration material that has been used at a given location. Because the distribution areas of forest tree species go beyond political borders, international cooperation on forest genetic resources is crucial. Finland is actively participating in several important networks on the field of conservation and use of forest genetic resources, especially within the FAO and EUFORGEN. Regional cooperation is highly important in the sustainable management of forest genetic resources and cooperation brings sustainable multilateral benefits.

The most urgent needs for development of the conservation programme are the characterisation of the conserved material and the subsequent evaluation of the conservation network. Genetic information of all individual conservation units should be generated in a systematic way and this information needs to be made available for all stakeholders. Ideally the methods and descriptors would be harmonized at regional level to enable further development of the existing pan-European network and development of widely applicable genetic monitoring programme. At national, regional and global level there are various processes that require reporting on forest genetic resources for monitoring and development purposes. To make these parallel processes coherent and cost-effective it is essential that all reporting is organised in a transparent way, with open and accessible data records.

Keywords: forest genetic resources management, genetic resources conservation, trees.

Tiivistelmä

Mari Rusanen[1)], Egbert Beuker[1)], Leena Yrjänä[1)], Matti Haapanen[1)] and Sanna Paanukoski[2)]

[1)] Luonnonvarakeskus (Luke)

[2)] Maa- ja metsätalousministeriö

Suomen maa-alasta kolme neljäsosaa on metsien peitossa. Metsien pinta-ala, 22,8 miljoonaa hehtaaria on pysynyt lähes muuttumattomana viimeiset 50 vuotta, samalla kun puuvaranto on kasvanut enemmän kuin 4 0% vuodesta 1997, ollen nyt 2 473 miljoonaa m^3. Samalla ajanjaksolla suojeltujen metsien ala on kolminkertaistunut.

Päivitetyn Kansallisen metsästrategian 2025 visio ”Metsien kestävä hoito ja käyttö on kasvavan hyvinvoinnin lähde” korostaa metsistä saatavaa monipuolista hyvinvointia ja sitä, että metsät tarjoavat ratkaisuja ihmisten ja yhteiskunnan tarpeisiin. Metsäsektori on Suomessa kestävän ja kiertotalouteen perustuvan biotalouden kulmakivi. Jalostetun metsänviljelyaineiston käyttäminen on jo parantanut merkittävästi metsien kasvua kolmella pääpuulajilla ja myönteinen kehitys jatkuu tulevaisuudessakin. Metsästrategia tunnistaa sen miten tärkeää geenivarojen suojelu ja kestävä käyttö ovat geneettisen monimuotoisuuden, metsien elinvoimaisuuden ja sopeutumiskyvyn ylläpitämiselle muuttuvissa ilmasto-olosuhteissa.

Suomen maa-, metsä- ja kalatalouden kansallinen geenivaraohjelma (2018) tuo ensimmäistä kertaa saman ohjelman piiriin kasvien ja eläinten geenivarat. Metsäpuiden osalta ohjelma määrittää suojelun tarpeen sekä päämenetelmät (*in situ* tai *ex situ*) kaikkiaan 14 puulajille, jatkaen ensimmäisen metsäpuiden geenivaraohjelman aloittamaa työtä. Näin ollen geenivarojen suojelu kattaa lähes kaikki taloudellisesti ja ekologisesti tärkeät puulajit Suomessa. Geenireservimetsiä on perustettu 44 kappaletta ja niiden kokonaispinta-ala on 7 218 ha (2020). Geenivarakokoelmia on perustettu yhdeksälle puulajille ja aineisto niihin on kerätty yhteensä 314 luontaisesta populaatiosta.

Metsäpuiden geenivaroja käytetään Suomessa kestävästi. Metsien uudistamisesta noin viidesosa tapahtuu luontaisen uudistamisen kautta ja neljä viidesosaa joko istutetaan tai kylvetään. Metsänomistajien keskuudessa on kasvava kiinnostus vaihtoehtoisia metsänhoidon menetelmiä kuten jatkuvapeitteistä kasvatusta kohtaan. Uusien menetelmien vaikutusta geneettisen monimuotoisuuteen ei tunneta ja näin ollen selvä tutkimustarve on olemassa. Suomella on pitkän aikavälin metsänjalostusohjelma kuudelle taloudellisesti tärkeälle puulajille. Ohjelmasta huolehtii Luonnonvarakeskus ja se on täysin valtion rahoittama palvelu. Jalostustavoitteiksi on määritetty tilavuuskasvu, puun laatu sekä sopeutuminen erilaisille kasvupaikoille ja ilmastoihin. Noin 60–70 % metsänviljelyssä käytetystä siemenestä tuotetaan siemenviljelyksillä.

Suomen ankarassa ilmastossa kylmänkestävyys on tärkeä ominaisuus ja erityisen tärkeää on optimaalisten käyttöalueiden määrittäminen sekä jalostetulle että jalostamattomalle metsänviljelyaineistolle. Metsänviljelyaineiston käyttäjiä varten on tehty uusia työkaluja auttamaan uudistamismateriaalin valinnassa ja jatkossa näitä välineitä tulee kehittää useammille puulajeille sekä tukea niiden käyttöönottoa. Jotta viljelyaineiston valinnan onnistumista voidaan seurata sekä kehittää edelleen päätöksenteon tukea ja säädöksiä, on erittäin tärkeää perustaa paikkatietoon perustuva järjestelmä, johon käytetyn viljelyaineiston alkuperä voidaan tallentaa.

Koska metsäpuiden levinneisyysalueet ylittävät hallinnolliset ja poliittiset rajat, kansainvälinen yhteistyö geenivarojen suojelussa on äärimäisen tärkeää. Suomi osallistuu aktiivisesti useiden merkittävien geenivarojen suojelun ja kestävän käytön verkostojen toimintaan, tärkeimpinä FAO ja EUFORGEN. Eurooppalainen yhteistyö on tässä erityisen tärkeää ja hyödyllistä kaikille osapuolille.

Geenivarojen suojelun kiireisimmät kehittämiskohteet ovat suojellun aineiston ominaisuuksien kuvaaminen ja suojelualueverkoston evaluointi tähän tietoon pohjautuen. Kaikista geenireservimetsistä ja kokoelmista tulee tuottaa systemaattista geneettistä tietoa ja tämä tieto tulee tuoda kaikkien toimijoiden saataville. Ihanteellisesti käytettyjen menetelmien ja kuvaajien tulisi olla yhdenmukaisia maanosassamme, jotta niiden perusteella voidaan kehittää eurooppalaista geenivaraverkostoa sekä monitoroida ohjelman edistymistä. Kansallisella, alueellisella ja globaalilla tasolla on olemassa useita prosesseja, joihin raportoidaan geenivaratyöstä. Rinnakkaisten prosessien yhdenmukaistaminen ja niiden taloudellisen tehokkuuden nostaminen on mahdollista, kun raportointi tapahtuu läpinäkyvästi ja tietosisällöt tuodaan avoimesti käytettäviksi.

Asiasanat: geenireservimetsät, geenivarat

Contents

1. The role of forests in Finland

In Finland there are about 22.8 million ha of forests, which equals 75% of the land area. Of this 60.9% is in private ownership, the state owns 25.4%, companies 8.2% and the rest, 5.5%, is owned by others. The total area of protected forests and forests under restricted use is 2.7 million hectares, or 12% of all forests. A quarter of this is strictly protected[1].

The forest area has remained almost unchanged over the last 50 years, whereas the volume of growing stock has increased by more than 40% since 1971, being now 2 473 million m^3 according to the Finnish National Forest Inventory[2]. In the same time, the area of protected forests has tripled. The use of genetically improved material in forest regeneration has significantly contributed to the increase of the annual increment of the growing stock for all three major tree species and will increasingly do so also in the near future.

The most common tree species in Finland are Scots pine (*Pinus sylvestris*) (50% of growing stock volume on forest land), Norway spruce (*Picea abies*) (30%) and birch (*Betula sp.*) (17%). Only 3% of the growing stock volume on forest land is other broadleaved species[2]. Due to this very limited number of dominant tree species, each having its own demands concerning growth place, and the rather homogeneous topography of the country without large elevational variation, large areas dominated by one single tree species are common in Finland. According to the national forest inventory, the annual increment of growing stock was 107 million m^3 (2009–2017). The annual increment has exceeded the annual felling by about 30%. The allowable sustainable felling potential of Finnish forests is estimated as 84 million m^3 per year for the years 2015 to 2024[1].

Only about 2% of Finland's surface is classified as other wooded land (801 000 ha FAO Global Forest Resources Assessment 2015), comprising mainly of peatlands and the subalpine region in Lapland. The forest genetic resources on peatlands or in the subalpine region have no specific role in the national forest genetic resources conservation programme. Scots pine growing on peatland may be phenotypically different from the same species on forest land but is considered genetically similar. In Lapland a subspecies of downy birch, namely *Betula pubescens* subsp. *czerepanovii* is an ecological key species, but because of its low importance in forestry it has not been so far included in the conservation programme.

The forest sector is the cornerstone of a sustainable and circular bioeconomy in Finland. Forest industry products accounted for more than 20% of the total value of Finnish goods exports in 2018. The value added (EUR 9.0 billion) generated by the forest sector in 2018 was 4.5% of the Finnish GDP, the highest share since 2007. The forest sector employed directly over 62 000 people[1]. Due to current increased forest industry investments and an increased sustained felling potential, forestry and the forest industry are expected to play a leading role in the Finnish bioeconomy also in the future. Wood-based fuels account for about 25% of the total energy consumption. Using wood for energy increases self-sufficiency in energy production, promotes good silviculture and reduces the use of fossil fuels. The share of wood-based fuels of all renewable energy sources accounted for over 83%[1].

Ecosystem services – benefits to humans derived from nature – are a significant source of welfare for Finnish people. The forest biodiversity creates the foundation for the ecosystem

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[1] https://jukuri.luke.fi/bitstream/handle/10024/544612/finlands-forests-facts-2019-EN-netti.pdf?sequence=3&isAllowed=y

[2] https://www.luke.fi/en/natural-resources/forest/forest-resources-and-forest-planning/forest-resources/

services derived from forests. Safeguarding well-functioning ecosystems is of key importance in the long term in order to guarantee the availability of ecosystem services for future generations. Natural capital must be utilised wisely. It is essential to recognise the interdependencies between different ecosystem services and to control them sustainably, using most recent scientific knowledge.

Forest-related services and the use and maintenance of non-wood products are important targets of forest management in Finland. A survey carried out in 2010 showed that 40,3% of the population picks mushrooms[3]. In a good mushroom year up to 16 million kg may be collected. In record year 2015 up to 64.5 million kg of berries were collected with a value of over 120 million euro[4]. Also game meat is an important non-wood product of Finnish forests. About 300 000 people carry a hunting licence and about 10 million kg of moose and deer meat is hunted every year[5].

Finland's forests are a considerable carbon sink. The annual net sink of forests varies annually mainly due to harvesting. The average sink has been about 32 million CO2 equivalent tonnes over the last 10 years. Concurrently the wood products gave a net sink of 2 million tonnes of CO2 annually. Active forest management can strengthen the forests' capacity to bind carbon and promote the replacement of fossil raw materials with wood-based products. In Finland, wood accounts for about 40 % of all building materials[1]. Wood as renewable raw material provides a long-term carbon sequestration potential, and thus is promoted for use in construction, above all for wooden building blocks of flats.

Forest genetic resources are a significant part of biodiversity. They provide the ability to develop cost-effective and sustainable ways of using natural resources and to improve the quality of the final products. This includes employing forest tree breeding to prepare for changes that are foreseen in our forestry. Finland's geographical location results in unique characteristics of our genetic resources, which creates a great motivation and also an obligation for conservation. Protection of genetic resources is an extremely long-term effort that is closely tied to the national preparedness for crises and risks and forms the basis for forest industry and other forest related businesses, enabling their further development. Forest genetic resources also represent culturally and historically valuable heritage.

Adaptation to a changing climate is of increasing importance when selecting the most suitable genetic resources for forest regeneration in the future. To produce innovative new products for a sustainable circular bioeconomy, specific wood quality characteristics will be of increasing importance. In the future the genetic variation in these characteristics will have to be characterised and included into breeding. There is also an intention to increase the forest biodiversity and the assortment of wood raw material by stimulating the use of some of the now minor tree species. This will also increase the demand for genetic material of those species.

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[3] https://wiki.aineetonkulttuuriperinto.fi/wiki/Sienestys
[4] https://wiki.aineetonkulttuuriperinto.fi/wiki/Marjastus
[5] https://stat.luke.fi/en/hunting

2. Finnish forest policies and legislation

Acknowledging the role of forests in the national economy, the general objective of the Finnish forest policy is to ensure the welfare founded on the sustainable use of forests while maintaining the natural diversity of the forests. The tools of forest policy are legislation, public funding and communication. Sustainable forest management has several dimensions: economic, environmental, social and cultural sustainability. Since 1948 the basic principle of Finnish forest legislation is the prevention of forest destruction. It is obligatory to regenerate the forest after clearcut. Finnish forests are managed to promote their biodiversity, e.g. ecologically valuable trees including dead and decaying trees stay behind at the site after logging, and care is taken to preserve valuable natural features including the habitats of endangered species.

The amendments to the Forest Act[6] that entered into force in the beginning of 2014 increase the freedom of choice of forest owners in managing their own forest property, improve the profitability of forestry and operating conditions of wood-producing industry, and enhance the biodiversity of forests. One important objective in the reform was to have less detailed regulation on the management of forests. The most important changes include allowing uneven-aged forest stands, abolition of age and diameter limits in regeneration, more diverse range of tree species, and increase in habitats of special importance. Notification of the establishment of seedling stands is no longer required and supervision is targeted to the success of regeneration, for which new minimum limits have been specified. Forest management promoting biological diversity has been a statutory requirement, ever since safeguarding biological diversity was enshrined as a parallel goal with wood production in the Forest Act in 1997.

An updated version of the National Forest Strategy 2025[7] was adopted by the Government in 2019. The vision of the updated Strategy is: Sustainable forest management is a source of growing welfare. The vision highlights the diverse welfare derived from forests and the point that forests provide solutions to people´s and society´s needs. Through forest policy a setting for a growing and responsible forest-based bioeconomy and circular economy as well as more diverse welfare can be created. The change in the operating environment emphasises the need to further strengthen the overall safeguarding of sustainability.

The vision and objectives of the Strategy remained primarily unchanged from those originally approved in 2015, but the project portfolio was updated to correspond to changes in the operating environment, aiming to achieve the 2030 Agenda goals related to forests and now taking into account climate sustainability and the safeguarding of forest biodiversity more clearly than before. Overarching themes in the strategy include digitalisation and increased communication and interaction. In addition to these, more of the projects in the strategy now take into account the diversification of forest management methods and of business and industry, along with the safeguarding of biodiversity and protection of water resources. Themes to be considered as crosscutting include the improvement of the availability and usability of forest, nature and environmental data and facilitation of their integration with other data sources. The cross-cutting themes include also building trust and cooperation between various actors with pluralistic communication and interaction. The strategy acknowledges the importance of both using forest genetic resources through breeding and the conservation of

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[6] https://www.finlex.fi/fi/laki/kaannokset/1996/en19961093.pdf
[7] http://urn.fi/URN:ISBN:978-952-366-006-9

genetic resources to guarantee genetic diversity, vitality and adaptability of tree species, in changing climatic conditions.

Although genetic resources remain a difficult concept for non-experts and there are challenges in the communication, the awareness of the value of genetic resources has been increasing in the past years. Partly this may be because of the legislative measures under Nagoya protocol on access and benefit sharing, which concretely demonstrate the potential value attached to genetic resources. Also, major disturbances such as the corona virus pandemic highlight the role of domestic genetic resources in security through agriculture and forestry. The conservation and sustainable use of forest genetic resources has become increasingly important due to climate change and their role has been acknowledged e.g. in the National Forest Strategy. In spite of ongoing research and a long tradition in provenance testing, the challenge remains to develop models and easily applicable tools to help forest owners in the choice of reproductive material, for all species (to learn about the about the existing tool see chapter 4).

According Finland's National Genetic Resources Programme for Agriculture, Forestry and Fishery[8] in order to meet its objectives – which are to couple the programme more tightly to the implementation of the natural resources policy and to extend the responsibility for the conservation of genetic resources to the private and third sector – it is required that the decision-makers and citizens be more aware of the conservation and use of genetic resources. Experts, officials and NGOs play an important role in making the concept more comprehensible. They must communicate clearly about the practical importance of the conservation and use of genetic resources for agriculture, forestry, fisheries, the environment and citizen well-being. To increase its effectiveness communication should be wide-ranging and diverse in terms of its content, target groups, methods and channels.

Breeding is the link between conservation, availability and use of genetic resources to food security and security of supply on a national scale. This requires an increased investment in the description and evaluation of genetic resources and a closer alignment between the objectives of the conservation of genetic resources and their use, including the production of bio-based products and new industries. Conservation is also linked to use when using seed from dynamic *ex situ* collections of the species that are currently underutilised (rare broadleaves). Finland's general policy on genetic resources in food and agriculture highlights a need to develop market-based conservation actions but at the moment this does not seem realistic for forest genetic resources.

Finland has not a specific legislation on conservation of forest genetic resources. The act on Trade in Forest Reproductive Material[9] implements the EU Council Directive 1999/105/EC on the Marketing of Forest Reproductive Material[10] (seeds or other seed units, parts of plants or planting stock of forest trees). It provides rules for the production, marketing and import of forest reproductive material. For a list of national policies and strategies that have specific links to sustainable management of FGR see Box 1.

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[8] https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162190/MMM_2020_05.pdf?sequence=4&isAllowed=y

[9] https://www.finlex.fi/fi/laki/kaannokset/2002/en20020241.pdf

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0105&from=EN

Box 1: National policies and strategies that have specific links to sustainable management of FGR

Finland's National Genetic Resources Programme for Agriculture, Forestry and Fishery
The programme covers the genetic resources of cultivated plants, domesticated animals, forest trees and fish. The Programme provides the guidelines for the preservation, conservation and sustainable use of genetic resources. The content and priorities of the Programme are guided by the changes in the operating environment.

Finland's Biodiversity strategy
The national strategy and action plan for the conservation and sustainable use of biodiversity, entitled "Saving Nature for People", was approved by a government resolution in December 2012. The main objective of the strategy is to halt biodiversity loss in Finland by 2020. It places economic and cultural values related to biodiversity at the heart of decision-making on the use of natural resources. The strategy also acknowledges the conservation of genetic resources for agriculture, forestry and fisheries.

The National Climate Change Adaptation Plan 2022
The aim of the National Climate Change Adaptation Plan 2022 is that the Finnish society has the capacity to manage the risks associated with climate change and adapt to changes in the climate. The objectives of the plan are: A. Adaptation has been integrated into the planning and activities of both the various sectors and their actors; B. The actors have access to the necessary climate change assessment and management methods, and C. Research and development work, communication and education and training have enhanced the adaptive capacity of society, developed innovative solutions and improved citizens' awareness on climate change adaptation. To reach the aim the key measures in support of adaptation to be implemented in the next few years are specified.

Finland's Forest Act
The purpose of the Forest Act is to promote economically, ecologically and socially sustainable management and utilisation of forests in order that the forests are productive in a sustainable way while their biological diversity is being preserved.

National Forest Strategy of Finland 2025 (updated)
The National Forest Strategy describes the priorities and measures for the development of forest-based business and activities, which the Government will focus on as part of the sector's joint development. The strategy's vision "Sustainable forest management is a source of growing welfare" highlights the diverse welfare derived from forests and the point that forests provide solutions to people's and society's needs. The strategy aims for overall sustainability and takes into account e.g. climate sustainability and the safeguarding of forest biodiversity more clearly than before. In the strategy it is stated that the genetic resources of forest trees will be ensured.

Finland's Long-term Tree Breeding Program
This program guides the long-term work of forest tree breeding in Finland (see chapter 4.1.).

3. Forest genetic resources conservation

The Forest Act lists 12 native (Table 1) and two exotic tree species (Siberian larch (*Larix siberica* or *L. archangelica*) and hybrid aspen (*Populus tremula* x *P. tremuloides*)) which can be used in forest regeneration. In general, the use of exotic species is quite limited in Finland, and no major change in this trend or in the policy is foreseen. Altogether there are 19 native tree species growing in Finland, as listed in Statistical Yearbook of Forestry 2010[11], but the number of woody species is more than 30. In the EUFGIS[12] database 33 woody species are listed as native to Finland (Table 1). However, some of these species don't reach a tree shape or height in Finland and are therefore not considered as target species in the national genetic resources programme but are of importance in the Forest Europe perspective. Still, the number of native tree species is low compared to most other countries. Some of the rare species that are not used in forestry have their main distribution on Åland Islands, the most important of these being the common yew (*Taxus baccata*) and the European crab apple (*Malus sylvestris*). According to the 2019 Red List of Finnish species[13] the threat category for the European crab apple, mountain elm (*Ulmus glabra*) and European white elm (*Ulmus laevis*) is vulnerable and for common ash (*Fraxinus excelsior*) and common yew have been categorised as near threatened. The number of tree species is expected to increase slightly in the future as some of the temperate forest species which currently grow in South-Sweden, eg. common beach (*Fagus sylvatica*), are expected to spread to Finland either naturally or by human intervention when the climate gets warmer.

The Finnish National Genetic Resources Programme for Agriculture, Forestry and Fisheries[14] lays out the need for conservation and primary methods for a total of 14 tree species; identifying if the main approach for a given species will be *in situ* (gene reserve forest) or *ex situ* (gene conservation collection) (Table 1). Thus, conservation is proposed for almost all financially or ecologically important tree species. Genetic resources of grey alder (*Alnus incana*), European aspen (*Populus tremula*) and willows (*Salix sp.*) have not been considered to require any special action because these species occur in large numbers in Finland, they are widely distributed outside commercial forests and they are not demanding in their habitat requirements. However, it may be that the status of the species, especially grey alder has to be reassessed in the coming years. European grab apple and common yew could be best conserved by the Åland islands authorities in their natural habitat.

The material to be conserved covers the existing adaptations to the different climate types in mainland Finland. Conservation of genetic diversity takes place either at the original location (*in situ*) in the environment in which the population developed its characteristics or outside the original location (*ex situ*). The selection of methods for each species is based on general knowledge of the reproductive biology and other properties of the species. The most important properties are the extent and continuity of the distribution area, abundance of flowering, efficiency of the spread of pollen and seeds and the abundance/rarity of the species in Finland.

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[11] https://jukuri.luke.fi/handle/10024/542406
[12] http://portal.eufgis.org/
[13] http://hdl.handle.net/10138/299501
[14] https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162190/MMM_2020_05.pdf?sequence=4&isAllowed=y

Table 1. The list of native tree species in Finland according to the EUFGIS database and primary and supportive methods of genetic conservation for those species identified in the Finnish National Genetic Resources Programme for Agriculture, Forestry and Fisheries.

Species	Primary method	Supportive method
Acer platanoides[3]	gene conservation collection	gene reserve forest
Alnus glutinosa[3]	gene conservation collection	
Alnus incana[2]		
Betula pendula[3]	gene reserve forest	
Betula pubescens[3]	gene reserve forest	
Corylus avellana		
Crateagus monogyna		
Crateagus rhipidophylla		
Frangula alnus		
Fraxinus excelsior[3]	gene conservation collection	gene reserve forest
Hippophaë rhamnoides		
Juniperus communis	gene conservation collection	
Lonicera xylosteum		
Malus sylvestris[1,2]		
Picea abies[3]	gene reserve forest	
Pinus sylvestris[3]	gene reserve forest	
Populus tremula[2,3]		
Prunus padus	gene conservation collection	
Prunus spinoza		
Quercus robur[3]	gene conservation collection	gene reserve forest
Rhamnus cathartica		
Salix caprea[2]		
Salix cinerea		
Salix myrsinifolia		
Salix pentandra[2]		
Salix repens subsp. *rosmarinifolia*		
Sorbus aucuparia	gene conservation collection	
Scandosorbus intermedia		
Taxus baccata[1,2]		
Tilia cordata[3]	gene conservation collection	gene reserve forest
Ulmus glabra[3]	gene conservation collection	
Ulmus laevis[3]	gene conservation collection	
Viburnum opulus		

1 Occuring on the Åland Islands only.

2 Species for which the need for conservation will have to be reconsidered in the future.

3 Species that can be used for regeneration according to the Forest Act.

The main tree species, namely Scots pine, Norway spruce, silver birch (*Betula pendula*) and downy birch (*Betula pubescens*), all have a wide continuous distribution. All of them also produce vast amounts of both pollen and seed which are effectively spread by wind. These species have been in the focus of many genetic studies in Europe and in Finland, and generally they contain a lot of genetic variation and although populations are differentiated in adaptive traits, the between population component in overall genetic variation is small[15]. Scots pine, Norway spruce and silver birch all have a well-established breeding programme (see chapter 4) and hence systematic testing has been performed for quality and growth traits. Adaptive traits such as the length of the growing period, timing of bud burst in spring and bud set in autumn have been assessed in long term provenance trials and the results are applied in breeding and in the use of forest reproductive material. No drastic reduction in the level of genetic variability is expected in the near future but the potential to cope with possible changes in the climate needs to be further studied.

The rare broad-leaved species grow in South Finland at the northern margin of their natural distribution area. They appear as individual trees or forming small populations. Because their distribution area is fragmented they are vulnerable to the environmental changes in climate and in land use. Many of the rare species also have limited seed production and some of them (European maple (*Acer platanoides*), small-leaved linden (*Tilia cordata*)) are insect pollinated which enforces the fragmentation. There is only little genetic research on the rare broad-leaved species going on in Finland and the marginal location limits the usability of results of Central-European studies[16].

3.1. *In situ* conservation of forest genetic resources

In situ conservation is used for common species that have continuous distribution and extensive gene flow. Consequently, *in situ* conservation is used as the principal method for Scots pine, Norway spruce, silver birch and downy birch. These species are also the main commercial species. The *in situ* genetic conservation units in Finland are called gene reserve forests. For Scots pine and Norway spruce, the network of gene reserve forests (Figure 1) is close to complete, capturing the country's adaptive variation within the species. Still, there are some regions where it has turned out to be difficult to find suitable areas and the network of conservation units is open for improvement as needed and feasible. In addition to the network of gene reserve forests for the main species, some gene reserve forests have been established as a supportive measure for rare species where the principal conservation method is *ex situ*. These species are small-leaved linden, common ash, European white oak (*Quercus robur*) and European maple.

A basic requirement for a gene reserve forest is that it is of local origin and has been either naturally regenerated or regenerated artificially with the original local seed source. The general objective is that a gene reserve forest of a wind-pollinated species should cover an area of at least 100 hectares, in order to secure sufficient pollination within the stand, but smaller units have been approved in particular for birch-species and the gene reserve forests of rare broadleaves are much smaller as a rule.

In the management of gene reserve forests the principal aim is to ensure abundant regeneration and wide gene pool. For the major species management does not differ much

[15] https://www.sciencedirect.com/science/article/pii/S0378112704003391
[16] http://dx.doi.org/10.14214/sf.1510

from normal forestry practices used in Finland. Most important aspect is to support natural regeneration and when this is not possible, seed to be used in sowing or planting must be collected from the very same stand. Special attention is also paid to creating and maintaining roughly even distribution of different age classes, in order to insure steady continuation. Seed is collected for *ex situ* back up, to be used in regeneration and as a safety precaution for hazards.

Table 2. State of *in situ* conservation of forest genetic resources in Finland 2020.

Species	Number of gene reserve forests	Area of gene reserve forests (ha)
Pinus sylvestris	21	4 078
Pinus sylvestris and *Betula sp.*	1	245
Picea abies	9	2 021
Picea abies and *Betula sp.*	1	111
Betula pendula and *B. pubescens*	6	670
Tilia cordata	2	24
Tilia cordata and *Acer platanoides*	2	15
Fraxinus excelsior	1	32
Quercus robur	1	22
Total	44	7 218

Normally a stand is selected as a reserve for one species, but in some cases a single unit may serve conservation of two species that grow naturally as mixed species in Finland. This has to be taken into consideration when reading the statistics for the number of units per species on one hand and the total area of conservation on the other hand. The total number of gene reserve forests in 2020 is 44 and the total area reserved for in situ gene conservation is 7 218 ha (Table 2, Figure 1).

The gene reserve forests are included in the owner's normal forest management planning system which includes detailed inventory and database to help the follow up. In addition, the stands are inspected by Natural Resources Institute Finland (Luke)17 staff in approximately five years interval and the necessary amendments in the management plan, based on gene conservation aspects, are negotiated and made. Luke organises seed collections in Norway spruce and Scots pine gene reserve forests and stores the seed for regeneration needs but also for research. As a curiosity, some lots have been sent to the Svalbard seed vault for long term.storage.

[17] https://www.luke.fi/en/

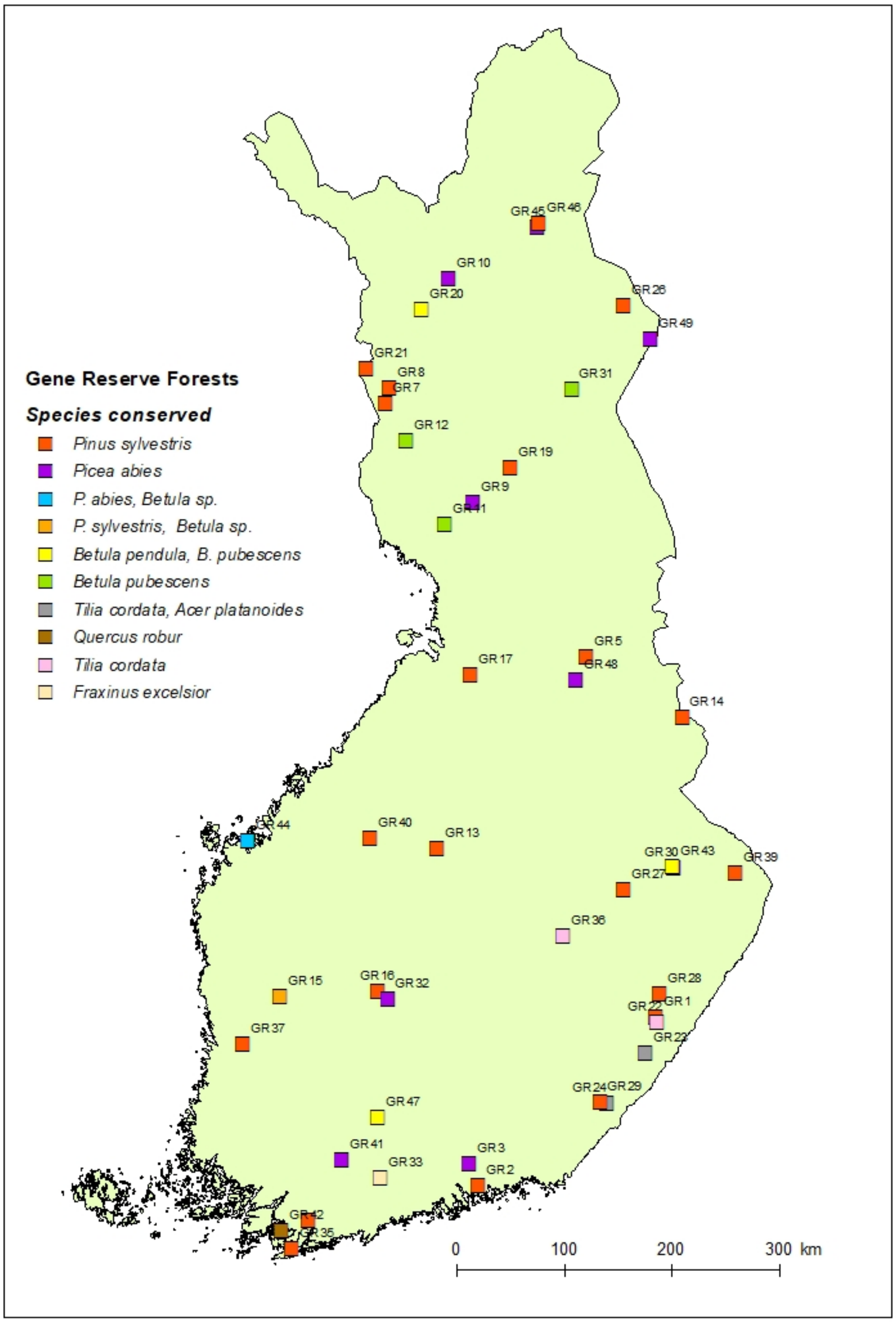

Figure 1. Network of Gene Reserve Forests in Finland

Valuable genetic resources exist also on strict nature conservation areas, but in Finland these areas are not considered to be part of the gene conservation programme. Nature conservation areas have their own management protocols for species and habitats conservation or special targets such as old growth forest protection. Most often it is not possible to include genetic aspects in these management plans. An exception is the Koli National Park in east Finland[18],

[18] https://www.nationalparks.fi/kolinp/history

where historical slash-and-burn agriculture is kept alive and the special type of management provides an opportunity for birch genetic resources conservation. Also for some species, such as common juniper (*Juniperus communis*) the protected habitats are essential for species conservation and also for the maintenance of within species genetic variation.

Luke is responsible for planning the network of gene reserve forests and selecting the conservation units. In general, the state would be the preferred landowner, but this is not possible for all species and regions. Around two thirds of the gene reserve forests are located on government land and are administered by Metsähallitus. One third is privately-owned, mostly by forest enterprises. No compensation is paid for gene reserve forests located on privately owned land and no legally binding agreements are made. The voluntary contracts have proved solid and are considered sufficient to give the gene reserve forests a designated status.

The networks of gene conservation units are estimated to be close to complete and no substantial increase in the number of units is foreseen. It may happen that some of the units must be removed from the list because of a change in the ownership or a major change in the land-use e.g. to road construction or mining industry. If this happens it may be hard to find a replacement and that’s why there is a need to develop methods for establishing a gene reserve forest from scratch or artificially move a gene reserve forest to another location in the same region. The most important research need is still to develop easily usable methods for systematic characterisation of the *in situ* conservation units using both molecular genetic methods and environmental data from various, existing sources.

3.2. *Ex situ* conservation of forest genetic resources

Ex situ conservation is mainly applied to tree species that are rare and grow either mixed with other species or in small stands. Often the distribution is fragmented and the genetic differentiation among populations is higher than for the major species. In the *ex situ* – programme the gene pool is primarily maintained in living trees, in gene conservation collections and is considered to be dynamic *ex situ* conservation. Material is collected from several small, natural stands and grown in an intensively managed collection (Figure 2). The collections are designed in a way that will make it possible to harvest seed at a later stage, to be used in landscaping or small scale forestry. However, there is no breeding involved since material is not selected according to any productive traits. The sampling is designed to capture the natural genetic variation as effectively as possible.

The gene conservation collections are established either with seedlings or with grafts, depending on the species (Table 3). This is because some of the species produce very little seed in Finland and even if there is seed available, it may be only from a couple of trees per stand, which reduces the genetic basis of the material. The original plan was to sample 10 trees per natural population included in the scheme, but for practical reasons the realised number of sampled trees/population may be lower.

The rare broadleaved species under *ex situ* conservation program have a very limited natural distribution in Finland and therefore there has been no need to define separate proveniences for these species.

Ex situ gene conservation in a strict sense is comprised of the actions under the national programme for gene conservation. The clonal collections of the national breeding programme or trials are not considered to be part of the national gene conservation programme and thus are not included in this report. Some genetic resources are conserved in university botanical

gardens and private arboretums. The arboretums have been valuable actors in making collections abroad and testing exotic tree species or provenances. However, in conservation of local provenances of native species their role is limited.

Table 3. State of *ex situ* conservation of forest trees in Finland in 2020.

Species	Collections		Material in the collections				
	number	area (ha)	stands	clones	families	ramets	seedlings
Acer platanoides	2	1.19	40		247		1 637
Fraxinus excelsior	4	0.95	26		136		965
Juniperus communis	2	0.44	60	187		1 397	
Prunus padus	1	0.04	6		11		75
Quercus robur	1	0.46	17		127		603
Sorbus aucuparia	3	1.57	48	30	169	300	1 566
Tilia cordata	2	2.12	79	277	20	345	167
Ulmus laevis	2	1.20	19	117		416	
Ulmus glabra	2	1.79	19	26		94	
Total	19	9.76	314	637	710	2 552	5 013

Static *ex situ* has only a minor role in Finnish forest gene conservation but seed from in situ conservation units of the conifers is stored systematically as a backup measure. Cryopreservation has not been in use, mostly because dynamic approaches have been given a priority and partly because of the cost of developing suitable methods. However, recent environmental changes stress the necessity to prepare for new, emerging pathogens and that is why a project has been initiated to cryopreserve some of the most threatened material, starting with mountain elm and European white elm.

In the future the need to establish more collections with new material will be very small, but there is a need to multiply the existing collections to a second place, as a backup function. The maintenance of the existing material is fairly intensive including regular inspections and management as needed. Skilled technical staff is needed, and it is important to maintain the knowledge and skills that have been acquired during the first decennia of the programme. There is also a need to characterize the material with molecular genetic methods and studies on adaptive traits. This will be important for both conservation and utilisation of the material. An emerging need is to learn more about resistance against pests and diseases and develop links between dynamic conservation, static conservation and use of genetic resources.

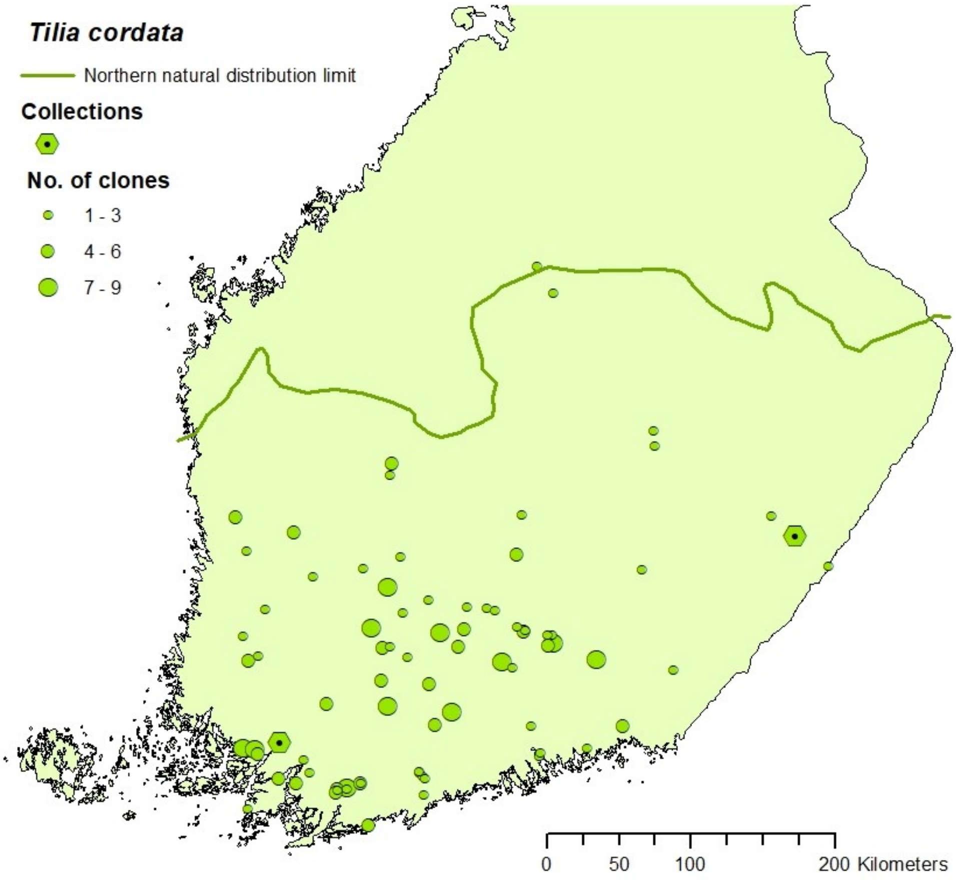

Figure 2. Gene conservation collections of small-leaved linden in Finland and the origins of the clones included. Similar maps for other tree species in gene conservation collections can be found in Annex 1.

3.3. Risks affecting forest genetic resources

The most important research needs on genetic diversity are linked to climate change: the adaptive potential of different species, resistance to emerging pests and diseases and how forest management should response to preserve genetic diversity. A key question is the choice of appropriate forest reproductive material, considering the long life span of trees. Genetic diversity of any tree species is not systematically monitored which also means that no procedure has been established to use genetic diversity as an indicator or an alarm mechanism. Modern molecular genetic methods are not yet used properly to support the conservation programme. There is a need to start characterising systematically the whole network of gene conservation units and for this the methods that are now used in research should be made available and usable for practical conservationists.

Severe forest damages are quite rare in Finland. At present, in general the health of Finnish forests is good[19], but climate change and invasive alien species increase the risk for damages. Occasionally forest damage occurs locally as the result of storms, snow, moose, deer or root rot (*Heterobasidium* sp). Forest fires have been successfully prevented through efficient fire

[19] https://jukuri.luke.fi/bitstream/handle/10024/545098/luke_luobio_85_2019.pdf?sequence=1&isAllowed=y

control. European spruce bark beetle (*Ips typographus*) which benefits from dry, hot summers, has started to cause serious damage in spruce forests in southern and south-eastern Finland during 2010–2013[17]. Ash dieback caused by *Hymenoscyphus fraxineus* has infected a great proportion of the ash populations, including the only ash gene conservation forest.

Risk management affects the selection of species used in regeneration and consequently narrows the possibilities for promoting species diversity. In severely infected root rot stands it is advisable to change the species composition, if possible. Often this would mean replacing Norway spruce with Scots pine or birch which in turn are susceptible to moose browsing. Moose and deer also prevent increasing the use of rare broadleaves that otherwise would be a good choice for biodiversity and landscape, at least on a small scale. Habitats where natural populations of the rare broadleaved species grow are protected according the Forest Act and furthermore the policy objective is to also increase the use of these species in forestry and landscaping.

Finland's National Strategy on Invasive Alien Species[20] highlights that the impacts of climate change in Finland will include strengthening of populations of already established alien species, the spread of already present alien species to new areas, increased harmful impacts of invasive alien species, and the entry into Finland of new invasive alien species. Many of the known potential invasive alien species occur in North America in areas similar in climate to Finland and there are no significant climate limitations to their spreading to northern Europe and establishing themselves in Finland.

[20]https://mmm.fi/documents/1410837/1894125/Finlands_national_strategy_on_invasive_alien_species.pdf/61137cdf-92ad-4ac8-8b6d-0feaeaedfe74

4. Use of forest genetic resources

The use of forest genetic resources in Finland can be described as sustainable. Approximately 80 % of forest regeneration in Finland is done through either planting or direct sowing whereas the proportion of natural regeneration is around 20%[21]. The use of genetically improved material is based on production on forest reproductive material of native tree species in seed orchards. The clones that are included in seed orchards are chosen after wide phenotypic selection of plus trees followed by progeny testing in field experiments. The breeding programme aims at good quality and high productivity, combined with a sufficient genetic variability. According to the Forest Act the stand may be re-established with seedlings or seed of certain species that are suitable to the site as regards their origin. The Finnish Food Authority[22] confirms the deployment areas for seeds collected from Finnish seed orchards and seedlings raised from them. For non-improved origins, recommendations on the suitable utilization areas and seed transfer are given in the Best Practices for Sustainable Forest Management by Tapio[23]. For material from outside Finland, Luke gives recommendations for utilization areas. Guidance is made to ensure that the material will be adapted to the climate of the location where it is used and a special effort is needed to take into consideration the predicted climate change (see more about a support tool Planters Guide in Chapter 5).

The annual need of seed for forestry is 10 000 – 12 000 kg[24]. Most of the seed is used for direct sowing of Scots pine. About half of the Scots pine forests are regenerated through direct sowing, using mostly genetically improved seed. Tree nurseries use approximately 1 500 kg of seed per year. According to the Finnish Food Authority the annual production of seedlings on Finnish nurseries vary between 155–180 million seedlings. At present the nurseries use genetically improved seed for 7 % of their production of plants of Scots pine, 75% of Norway spruce and 93% of birch[25].

According to the Finnish Food Authority in Southern Finland[26] the supply of seed orchard seed covers the demand of the nurseries for the main species: Norway spruce, Scots pine and silver birch. The production of material under the OECD-category 'tested' for Scots pine covers up to 70% of the total use by the nurseries in Southern Finland. The use of seed stands (category 'selected') has diminished as the production capacity of seed orchards has grown to meet the demand. In the Northern part of the country, the production of seed orchard seed is considered insecure due to insufficient ripening of the seed in the harsh climate conditions. To secure the availability of pine seed for the Northern part of the country, cone collections from known locations in a region of provenance (category 'source-identified') are also needed. Seed of category 'source identified' is mainly used for direct sowing of Scots pine.

Years of abundant seed production are irregular especially for Norway spruce, which has caused periodically a shortage of seed. The production capacity of Norway spruce seed orchards does not meet the annual demand. Mass collections of spruce cones are arranged

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[21] https://stat.luke.fi/sites/default/files/suomen_metsatilastot_2019_verkko2.pdf
[22] https://www.ruokavirasto.fi/en/farmers/plant-production/forest-tree-seed-and-seedling-production/
[23] https://www.slideshare.net/MetsaTapio/best-practices-for-sustainable-forest-management-in-finland
[24] https://mmm.fi/documents/1410837/1504826/Siementuotannon+kehitt%C3%A4misryhm%C3%A4n+raportti+9.2.2018.pdf/b1d5d422-8c6a-4c4b-b424-a8743f1bbccc/Siementuotannon+kehitt%C3%A4misryhm%C3%A4n+raportti+9.2.2018.pdf.pdf
[25] https://stat.luke.fi/sites/default/files/suomen_metsatilastot_2019_verkko2.pdf
[26] https://www.ruokavirasto.fi/viljelijat/kasvintuotanto/metsapuiden-siemen-ja-taimituotanto/

whenever possible, approximately once in five to ten years. To complement the supply from seed orchards source identified spruce seed is sometimes collected in connection with loggings of Norway spruce stands.

International trade of forest reproductive material takes place within the European Union, mostly between the neighbouring countries, Sweden and Estonia (Table 4). The number of imported seedlings is about 4% of the total amount of seedlings produced in Finnish nurseries. The amount of imported seedlings includes seedlings grown in foreign nurseries from Finnish seed.

Table 4. The quantity of FRM transferred internationally in 2018

Species	Quantity of seed (kg)		Number of seedlings	
	Import	Export	Import	Export
Picea abies	41	0.54	6 472 000	2 139 000
Pinus sylvestris	2	59.20	766 000	675 000
Betula pendula	1	0.09	15 000	273 000
*Other conifers		0.15		518 000
*Other deciduous	22			30 000

* Other species include, for instance, *Betula pubescence*, *Betula pendula* var. *carelica*, *Quercus robur* and *Larix siberica*. Source: Finnish Food Authority

According to the Finnish Food Authority in Finland there is a total of 107 productive seed orchards for Scots pine, Norway spruce and Siberian larch with a total area of nearly 1 700 ha. They are owned and managed by private companies. In 2016 there were 42 nurseries in Finland producing 158 million forest tree plants (100 million Norway spruce, 50 million Scots pine, 6.7 million silver birch and half a million other species). Most of the plant production for the three major tree species is concentrated in large modern nurseries with capacities up to over 10 million plants per year. Smaller nurseries purchase seed from the main actors or import plants and seed from Swedish or Estonian origin. Some seedlings are grown in Estonia from Finnish seed and then imported back to Finland. In addition, there is a number of smaller nurseries that grow plants of minor species also, such as Siberian larch, Lodgepole pine (*Pinus contorta*), masur birch (*Betula pendula* var. *carelica*), black alder (*Alnus glutinosa*) and European white oak.

Only a few species are used in Finnish forestry but there is a demand to widen the selection of species. A newly funded project will study the possibilities to bring new species to market. To enable this the Finnish *ex situ* conservation units will be registered as seed sourced for forest reproductive material. This will improve the supply of seed of several native noble hardwood species in case the demand on the market increases.

The main challenges for the productivity of Norway spruce seed orchards are related to flowering as well as cone pathogens and insects. To overcome these restrictions a project has started to create protocols and practical procedures for somatic embryogenesis of bred Norway spruce material. The aim is to increase the production by multiplying crossed progenies of elite plus trees. This will enhance the benefits gained from breeding compared to that of seed orchards.

The Council Directive 105/1999 on the Marketing of Forest Reproductive Material[27] is adopted to the national legislation and implemented and enforced by the Finnish Food Authority. This directive guides the marketing and thus indirectly also the use of forest reproductive material, which is the most essential part of forest management from the point of view of genetics. The directive does not guide genetic diversity as such but in addition there are national recommendations to ensure that the genetic diversity of improved forest reproductive material is kept at a sufficient. The minimum number of clones in a seed orchard is kept high (25–35) to secure long-term diversity in the produced seed. The seed orchards are also carefully planned and designed so that the clones within a seed orchard are unrelated to each other. In order to minimize the risk of failure due to too large transfers of the produced seed, a deployment area has been defined for each individual orchard. In addition to this a decision support tool "Planters Guide"[28] was developed to enable forest owners and managers from both Sweden and Finland to choose the most optimal Scots pine seed orchard for their need from both Sweden and Finland[29]. The tool includes effect of climate change for different scenarios, estimated genetic gain as the result of breeding as well as the effect of pollination from outside the orchard. On the basis of a grid (4 x 4km in Sweden and 10x10 km in Finland) the tool provides for each seed orchards an index that relates the overall performance of its seed with that of a local, non-improved seed source. Also separate indexes for growth and survival are provided. At present a similar system is developed for Norway spruce with Finland, Sweden, Norway and possibly the Baltic countries. This work is carried out within the EU H2020 B4EST project. Within this project the suitability of the Planters Guide system for also other tree species in other European regions is investigated.

4.1. Genetic improvement and breeding programme

Finland has a long-term tree improvement programme for six tree species, namely Norway spruce, Scots pine, silver birch, Siberian larch, black alder and hybrid aspen. The breeding programme is managed by the Natural Resources Institute Finland (Luke) as a fully state-financed public service. Seed orchards are owned by two commercial companies. Metsähallitus provides state-owned sites for genetic testing and give support in the field-test establishment work.

Breeding goals for all species include volume production on a per area basis, timber quality and adaptedness to various sites and climates. Cold hardiness is an important trait in the harsh climate of northern Finland. Breeding materials are organized into multiple populations with different climatic targets. Besides native breeding materials, the programmes of Scots pine and Norway spruce include an additional infusion population which comprises plus trees from regions south of Finland. Breeding strategies vary according to the biological properties of the species. Regeneration of the best breeding materials takes place through controlled crossing which are conducted according to the principle of positively assortative mating. The full-sib families are tested in the field trials both by seedlings and clonal propagules (cuttings).

The currently established seed orchards comprise grafts of the best progeny-tested plus trees, whereas their full-sib progenies will be deployed in upcoming 2nd generation seed orchards.

[27] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0105&from=EN
[28] https://www.skogforsk.se/plantersguide
[29] https://www.skogforsk.se/cd_20190513082142/contentassets/3ee3a4dbb7c04dc48f1c900690d57f23/arbetsrapport-1017-2019.pdf

Mass propagation technologies based on somatic embryogenesis have recently been developed for Norway spruce. The first clonal mixture was registered for operational use a few years ago. About 60–70% of the reforestation materials are produced in seed orchards. Genetic gains in productivity vary from 10% to 20% depending on the genetic level of the reforestation material.

Application of genomic selection is currently investigated in one of the breeding populations of Scots pine. Operational applications of genomic selection in breeding are not in sight yet mainly because of the high cost of genotyping. Genetic markers have been used to identify Norway spruce trees showing greater resistance to root-rot. Furthermore, recent studies have addressed silver birch as a model species for genome wide association study analyses.

5. Institutional framework for the conservation, use and development of forest genetic resources

In Finland the work on genetic resources for agriculture and forestry is steered by the Ministry of Agriculture and Forestry[30] which is responsible for implementation of the forest policies in Finland, including policies regarding the use and conservation of forest genetic resources. The Ministry also provides funds for the national programmes, such as Finland's Long-term Tree Breeding Program and the genetic resources conservation programme. The Natural Resources Institute Finland (Luke), Metsähallitus as well as the Finnish Food Authority, which are all three much involved in the use and conservation of forest genetic resources in Finland (see below), all act under the direct supervision of the Ministry.

The Advisory Body for Genetic Resources, established by the Ministry of Agriculture and Forestry, oversees the implementation of the programme, acts as a link between different ministries in matters related to genetic resources, participates in legislative drafting on the topic and processes Nordic and international genetic resource initiatives. The body, however, does not have any executive powers. The board contains representatives from various ministries, research institutions, educational institutions, authorities and breeding organizations, businesses and associations. The Åland Island government is also represented on the board.

The Advisory Board for Forest Tree Breeding, also under the Ministry of Agriculture and Forestry, monitors and supports Finland's Long-term Tree Breeding Program and to promote the use of the results of tree breeding through a programme for establishment of seed orchards. In addition, the board follows the activities in research and development.

In accordance with the Act on Natural Resources Institute Finland (561/2014), Luke is responsible for the conservation of genetic resources. Luke acts as the coordinator of the implementation of Finland’s National Genetic Resources Programme for Agriculture, Forestry and Fishery for the entire genetic resources sector and maintains most genetic resources collections under the national genetic resources programme. Luke collaborates widely with stakeholders associated with the maintenance and sustainable use of genetic resources. Luke performs the tree breeding activities in Finland in according with Finland's Long-term Tree Breeding Program and is consulting in the establishment and management of seed orchards.

Metsähallitus[31] (State Forest Enterprise) runs business activities while also fulfilling many public administration duties. Metsähallitus administers more than 12 million hectares of state-owned land and water areas. Majority of the gene reserve forests are located at state owned forests and managed by Metsähallitus as well as the land where the majority of field trials and collections of the Finnish Tree Breeding Program are located. National parks and other nature conservation areas, that are very important for the conservation of biodiversity on a wider scale, are managed by Metsähallitus.

The Act on Trade in Forest Reproductive Material is enforced by the Plant Health Unit of the Finnish Food Authority[32]. The aim of supervision is to ensure the high quality of basic material used for producing forest reproductive material, the compliance of seeds and seedlings on the

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30 https://mmm.fi/en/frontpage
31 https://www.metsa.fi/web/en
32 https://www.ruokavirasto.fi/en/farmers/plant-production/forest-tree-seed-and-seedling-production/

market and that buyers gain the necessary information in support of selecting material suitable for a specific purpose.

There are several research projects at a national level in Finland on the conservation and use, including breeding, of forest genetic resources. They are carried out by Luke and several universities, often in cooperation.

6. International and regional cooperation on forest genetic resources

Because the distribution areas of forest tree species go beyond political borders, international cooperation on forest genetic resources is crucial. Finland is a party to all the major multilateral environmental agreements and processes which are relevant to forests, such as United Nations Forum on Forests UNFF, United Nations Framework Convention on Climate Change UNFCCC, Convention on Biological Diversity CBD, as well as the work on forests in the United Nations Food and Agriculture Organization (FAO). FAO is an important forum for influencing development policy in agriculture, forestry and fisheries.

On regional co-operation the Forest Europe process (former MCPFE) is important in itself and in particularly because of the close link to the EUFORGEN-programme. Important work in the forest sector is being done at the United Nations Economic Commission for Europe – Timber Committee (UNECE/TC). Under the Nordic Council of Ministers NordGen Forest with its Forest Regeneration Council and Working Group for Forest Genetic Resources is an important meeting place for Nordic experts in the field.

Finland takes part in several important networks on the field of conservation and use of forest genetic resources (see Box 2). Finland provides information to the different networks for regular reports and to international databases on forest genetic resources, such as EUFGIS and FOREMATIS. Finnish organisations, especially Luke, are and have been participating in many international research and development projects, especially EU framework projects (Evoltree, Trees4Future, TreeBreedex, B4EST, GenRes Bridge, FORGENIUS).

International networks, most important EUFORGEN, provide support for activities at national level and help to follow the key policies and developments in Europe. The value of peer support also on practical level is high. Access to and creation of international databases with harmonized concepts and data standards is an important benefit of international and regional cooperation. The development of common protocols for the practical use and conservation of forest genetic resources is stimulated through international cooperation. This is valid especially at a regional level for countries with similar forest ecosystems and similar commercial interests, such as the Nordic countries.

There are several global or regional threats to the diversity of forest genetic resources, such as climate change and new and/or invasive pests and diseases that can only be effectively dealt with through international cooperation. An example this is the reaction to the Ash dieback disease In Europe. Through existing networks it was possible to set up rapid monitoring and research projects to find ways to react to the fast spreading of the disease.

Also the question of monitoring the state and changes in forest genetic resources is something where international cooperation is needed for developing methods, creating political will, and finally creating a monitoring system. Techniques to better characterise the forest genetic resources are being developed in European cooperative projects, such as FORGENIUS.

Cooperation between actors working on genetic resources in other sectors (agriculture animal, pathology) or working on wider biodiversity will increase the sustainable practices in management of genetic resources. Together the sectors will also have a stronger voice towards politicians and decision makers. In the frame of the EU H2020 project GenRes Bridge[33] conservationists of genetic resources of plants, animals and forestry are preparing a common strategy.

Box 2: Relevant international organisations and networks that Finland is participating in

FAO

The FAO Global Plan of Action (GPA) for the Conservation, Sustainable Use and Development of Forest Genetic Resources, was adopted by the FAO Conference at its 38th session in June 2013. This Global Plan of Action identifies 27 strategic priorities grouped into 4 areas: 1) improving the availability of, and access to, information on FGR; 2) conservation of FGR (in situ and ex situ); 3) sustainable use, development and management of FGR; 4) policies, institutions and capacity-building. Implementation of the Global Plan of Action will strengthen the sustainability of the management of FGR while contributing towards the Millennium Development Goals, the post-2015 agenda and the Aichi Biodiversity Targets. Finland implements the GPA for the Conservation, Sustainable Use and Development of Forest Genetic Resources.

OECD

The Organisation for Economic Co-operation and Development OECD is an important institute for international economic research and a think tank for policy planning. Finland is one of the participating countries in the OECD Forest Seed and Plant Scheme. Under this the OECD Scheme for the Certification of Forest Reproductive Material seeks to encourage the production and use of forest tree seeds or plants that have been collected, processed, raised, labelled and distributed in a manner that ensures their trueness to name. This certified material is intended for use in a variety of forestry functions, including timber production, soil protection, and environmental criteria. The OECD Scheme for the Control of Forest Reproductive Material Moving seeks that seeds and plants are produced and officially controlled according to harmonised procedures which are also aligned with the EU Directive 105/1999 on the marketing of forest reproductive material.

EUFORGEN

EUFORGEN – the European Forest Genetic Resources Programme – is an international cooperation programme that promotes the conservation and sustainable use of forest genetic resources in Europe as an integral part of sustainable forest management. It was established in 1994 as a result of a resolution adopted in 1990 by the first Ministerial Conference of the Forest Europe process. Regional cooperation is highly important in the sustainable management of forest genetic resources and cooperation brings sustainable multilateral benefits. EUFORGEN coordinates the European-level conservation, supports countries in the implementation of the national programmes and has got central role in monitoring the progress as well as in reporting in a harmonised manner to the Forest Europe process.

EUFGIS

One task of EUFORGEN is the maintenance of the European Information System on Forest Genetic Resources EUFGIS. EUFGIS serves as a documentation platform linking national inventories on forest genetic resources in Europe. This supports the countries in their efforts to conserve forest genetic resources as part of sustainable forest management, as agreed in the context of Forest Europe, the pan-European forest policy process. The EUFGIS portal provides geo-referenced information on the conservation of forest genetic resources in Europe and access to detailed data on dynamic gene conservation units of forest trees in different countries. The data is provided and frequently updated by national focal points based on pan-European minimum requirements and data standards for the units.

[33] http://www.genresbridge.eu/

The countries can use EUFGIS for various reporting efforts, such as the State of Europe's Forests and the State of World's Forest Genetic Resources reports. It can also be used for identifying gaps in genetic conservation efforts within the distribution ranges of forest trees, developing gene conservation strategies for forest trees at pan-European level and sampling tree populations for research purposes.

NordGen

NordGen – the Nordic Genetic Resource Center – is a Nordic organization dedicated to the safeguarding and sustainable use of plants, farm animals and forests. NordGen Forest serves as a Nordic meeting place to examine issues in the fields of forest genetics and genetic resources, supply of seeds and plants, and methods for regeneration. The main goal is to contribute to the establishment of the best possible Nordic forests for the future. NordGen Forest consists of two bodies, each with members from all Nordic countries: The Council seeks to increase the availability of suitable forest reproductive material and to promote successful forest regeneration in the Nordic countries. This includes both practical and administrative parts of seed and plant supply, regeneration methods, genetics and tree breeding. Its members exchange information on regeneration issues, discuss different topics of interest to Nordic forestry, and plan coming events. The Working Group on Genetic Resources ensures cooperation and initiates and implements activities to support the conservation and use of forest genetic resources.

FOREMATIS

The European Commission's Forest Reproductive Material Information System (FOREMATIS) provides a search tool for forest breeders, forest nurserymen, experts and the general public, functioning as a repository linked with Member States data of planted forest tree species. FOREMATIS provides access to the data of the national registers, containing the details of approved basic material including data on areas and geographic location – essential for determining if a particular material is suitable for a site.

7. Challenges and opportunities: recommended actions for the future

The genetic conservation of forest trees in Finland has been running since 1992 and is quite well established. Basic information on genetic resources in the national conservation and breeding programmes is well recorded and made available for the experts in the field through the register on forest genetic resources, managed by the Natural Resources Institute Finland (Luke). However, it could be improved with accurate genetic information on the conservation units. Based on this genetic information, gap analysis of the network should be carried out on both national and regional level. In the analysis special attention should be paid to the effects of climate change on the existing units.

Ideally the methods and descriptors would be harmonized at regional (European) level, to enhance a wider usability of the data. For the users of forest reproductive material there are new tools to assist in making the right choice of regeneration material but there is still a need to promote the use of these tools and to expand their usability to a wider selection of species. At national, regional and global level there are various processes that require reporting on forest genetic resources for monitoring and development purposes. To make these parallel processes coherent and cost-effective it is essential that all reporting is organised in a transparent way, with open and accessible data records.

The number of tree species in Finland is low but still not all the species are covered by the conservation programme and there is a need to make science-based prioritisation on how to expand the programme, considering in a balanced way the threats, ecological significance and economic value of each species. The Finnish programme is firmly based on a dynamic *in situ* -approach but the advantages of using static *ex situ* conservation for some specific threatened species or populations should be further analysed. A link between conservation and use must be strengthened in order to help the forests in adapting to the new climatic conditions and to support the forest owners particularly in decision making during the regeneration phase

In the use and management of forest genetic resources the biggest challenge is how the ongoing changes in climate can be dealt best. In the breeding programme there is plenty of information available on the adaptive traits and this information will be used in the recommendations for deployment areas to the forest owners. For monitoring the success and for adapting the decision support tools as well as the regulations, it will extremely important to set up a geo-referenced system that keeps records on the origin of the regeneration material that has been used at a given location.

Forests and forestry are important in Finland and forest-related policies are developed with participation of the stakeholders. However, the value of within-species genetic variability is still poorly recognised and there is a need to communicate its importance to the general public, forestry professionals and policy makers. There have been conflicts related to the management of gene reserve forests, mainly due to misperception of the role of gene reserve forests. Such conflicts should be avoided through improved communication.

The use of genetic resources should be better integrated to conservation and the links between forest gene conservation and various policies, most notably biodiversity and habitat conservation, should be made more visible and strengthened, at both national and European levels.

There has been little use of clonal material so far, but recent developments in vegetative propagation techniques for conifers, especially Norway spruce, may change this. Its effect on the genetic diversity will have to be assessed and they are taken into consideration, for example when defining requirements for the minimum number of clones to be included in clone mixtures or maximum number of plants that can be produced per clone.

During the last decade there has been an increasing interest in continuous-cover silviculture as an alternative for the traditional clear-cut method. With continuous-cover silviculture the principal regeneration method is natural regeneration. Such alternative method may have a positive effect on genetic diversity because of the trend towards shorter rotation time and increased economic productivity in commercial forestry. On the other hand, deterioration of genetic diversity may happen due to repeated removal of largest and best quality trees and thus a reduction of the role of those trees in seed production for regeneration. There is an urgent need to study the effect of continuous forestry on genetic diversity.

The importance of forests as a major carbon sink is increasing in the battle against climate change. This implies a need to increase the standing volume of wood in Finland. The use of genetically improved reproductive material and faster growing species is important in reaching the goal. The conservation of biodiversity is another trend where forest genetic resources have an important role. In addition to increasing the area of strictly protected forests, attention should be paid also to biodiversity targeted management guidelines and practices.

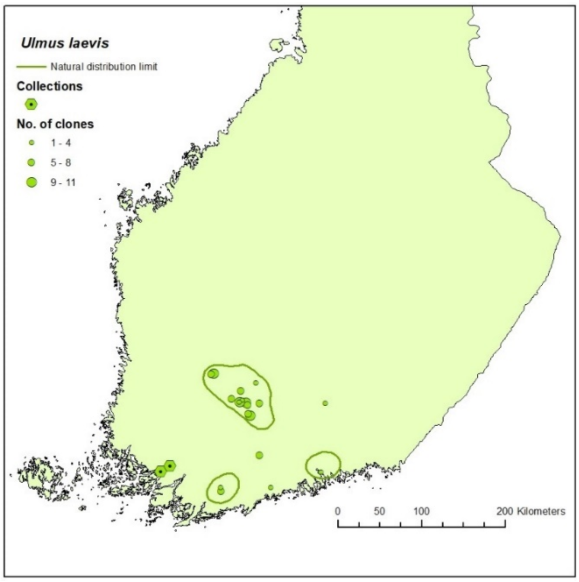
The development of new innovative products from wood as part of the development of a circular bioeconomy will also put new demands on the physical and chemical quality of wood as raw material. There is already an initiative by the Ministry of Agriculture and Forestry to increase the assortment of wood to be produced in the Finnish forests by promoting the use of native tree species that have had a very minor role in today's forestry. These trends may require changes both in goals of the existing tree breeding program and initiation of breeding for new species.

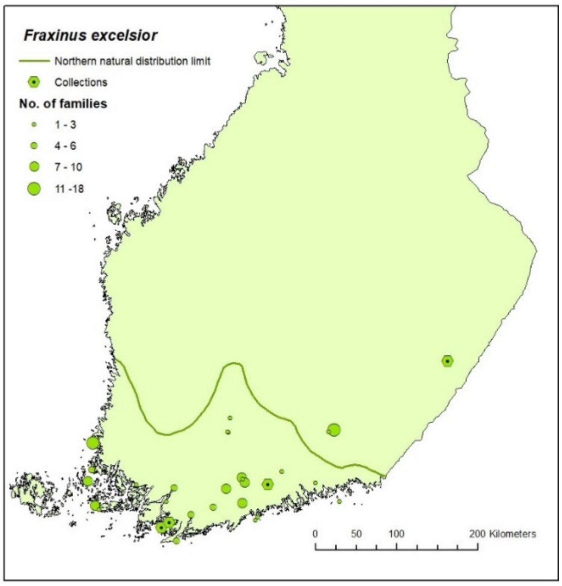
The development and use of digital applications for the management of data on forest genetic resources should be intensified. An online information system for geo-referenced records of the origin, movement and use of forest reproductive material would be very helpful for the management of genetic resources in a changing climate and regarding new emerging threats.

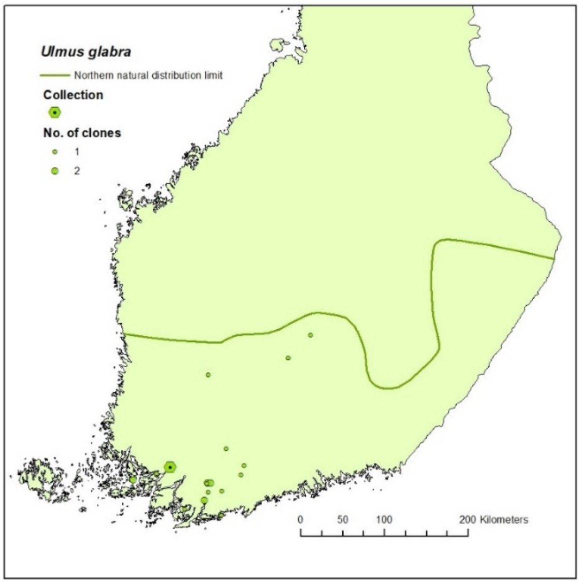
New know-how and technologies should be developed and taken into practice. Molecular techniques to characterise the GCUs, and to monitor the status and changes of the genetic diversity are rapidly developing and will be taken into practice in the near future through international cooperation (H2020 project FORGENIUS).

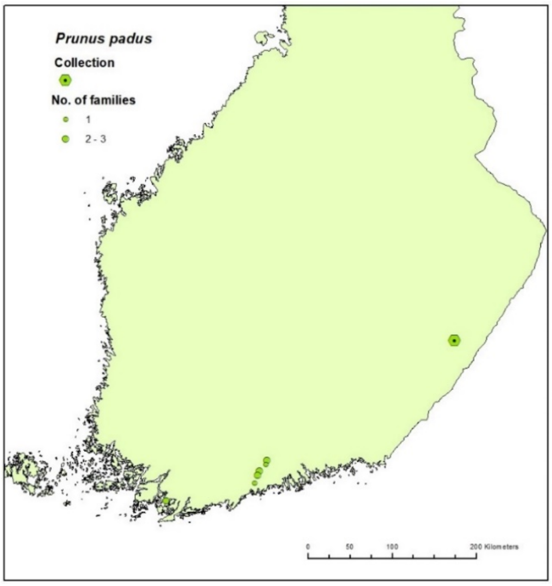
The use and conservation of forest genetic resources should get more attention in the education of forestry professionals at all levels, also to create a better awareness within the whole forestry sector about the importance of conserving the genetic variability of forest tree species, as well as about the benefits of using genetically improved reproductive material. Also, the role of the forest owners in the process of use and conservation of forest genetic resources should get more recognition.

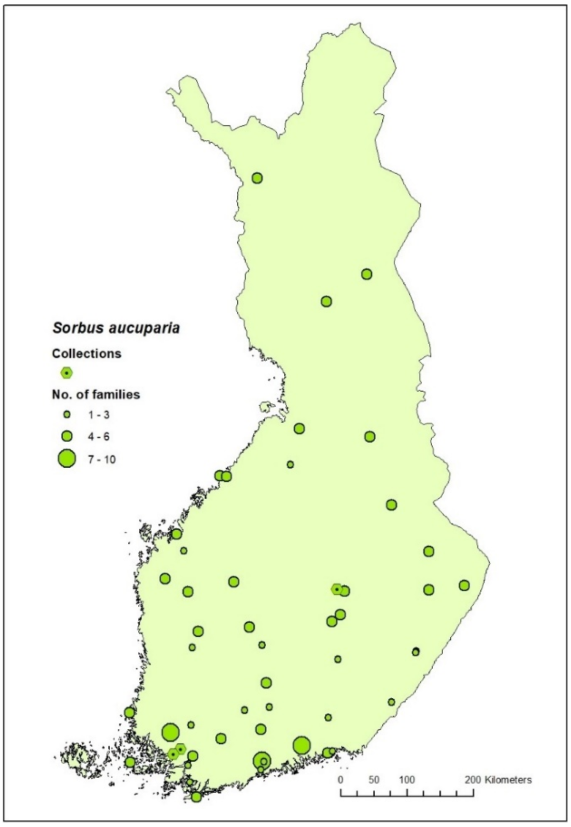
Appendix 1. Gene conservation collections for different tree species in Finland and the origins of the clones included.

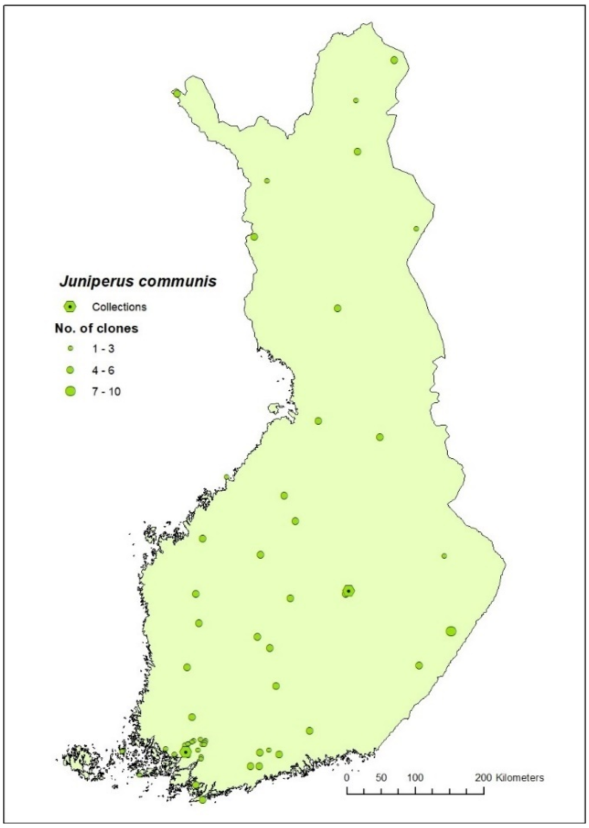


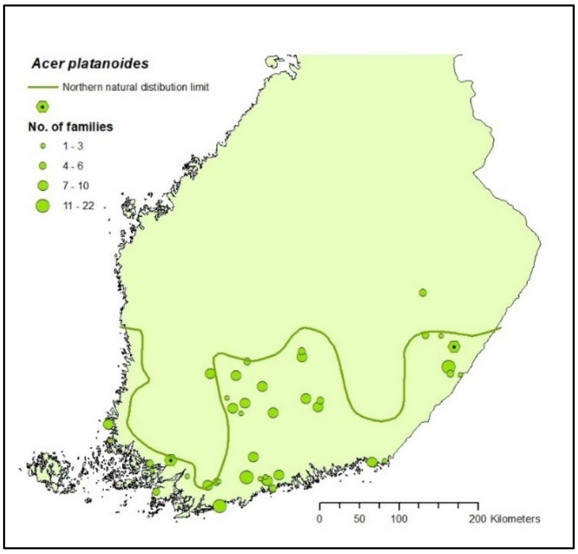


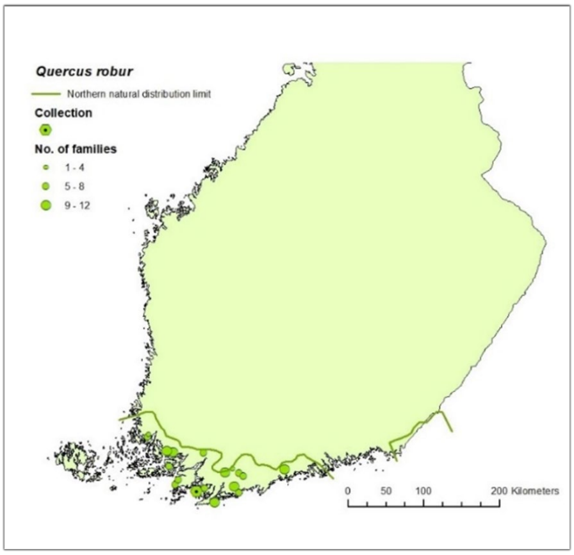





Sorbus aucuparia
Collections
No. of families
1 - 3
4 - 6
7 - 10
0 50 100 200 Kilometers


Juniperus communis
Collections
No. of clones
1 - 3
4 - 6
7 - 10
0 50 100 200 Kilometers


Acer platanoides
Northern natural distibution limit
No. of families
1 - 3
4 - 6
7 - 10
11 - 22
0 50 100 200 Kilometers


Quercus robur
Northern natural distribution limit
Collection
No. of families
1 - 4
5 - 8
9 - 12
0 50 100 200 Kilometers

luke.fi

Natural Resources Institute Finland
Latokartanonkaari 9
FI-00790 Helsinki, Finland
tel. +358 29 532 6000