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Contents

This document has been developed by the NordGen Forest Working Group on Genetic Resources, together with the secretariat of NordGen Forest .

The Nordic countries cooperate on exchanging information for the conservation of forest genetic resources through NordGen Forest, under the Nordic Genetic Resource Centre (NordGen). NordGen Forest is a body dedicated to forest regeneration, plants, seed and management of genetic resources.

NordGen Forest consists of two bodies; the NordGen Forest Regeneration Council and the Working Group on Genetic Resources. All five countries are represented in both bodies. The objective of the Working Group on Genetic Resources is to ensure cooperation on conservation and use of genetic resources of forest trees and facilitate knowledge exchange among the Nordic countries.

NordGen has its head quarters i Alnarp, Sweden. The secretariat of NordGen Forest is located at the Norwegian Institute of Bioeconomy Research (NIBIO) in Ås, Norway.

Summary

The importance of conservation of forest genetic resources is widely recognized and efforts are needed on national, Nordic, European and global levels. The Nordic countries cooperate on exchanging information for the conservation of forest genetic resources through NordGen Forest, under the Nordic Genetic Resource Centre.

The forest genetic resources are valuable at many levels and are critical for long-term forest sustainability in a changing climate. Consequently, the present and future human use of the ecosystem services provided by the forests depends on the genetic resources. The key objective of genetic conservation is to maintain the adaptive diversity of forest tree populations. Genetic diversity ensures that forest tree populations, and consequently species, adapt to and evolve under changing environmental conditions. Genetic diversity also provides resilience to pests and diseases, and by this maintains forest vitality.

The aim of this report is to highlight the status of forest gene conservation in the five Nordic countries, how the conservation of forest genetic resources is implemented, as well as strengths and challenges ahead. The report focuses mainly on *in situ* conservation of forest trees, based on the agreed minimum requirements within the European Forest Genetic Resources Programme (EUFORGEN). Other types of gene conservation are described in general and are addressed for some countries, but not in a systematic comparative way and the level of detail may vary among countries.

The commitments to implement the FAO Global Plan of Action for Forest Genetic Resources and the Pan-European strategy for genetic conservation of forest trees lie at the national level. Countries in the Nordic region do however support and complement each other when it comes to conserving genetic diversity.

There is a need to further develop the European work at the Nordic and national level, including the development of more specific climatic zoning to assess the genetic diversity conserved. There is also a need for a systematic evaluation of how the so called Genetic conservation units (GCU) established under the European programme cover the species genetic diversity in the Nordic region. Evaluation, identification of conservation gaps, as well as characterisation of genetic variation captured by the GCU units, could be further developed in cooperation on a Nordic level.

There is a question whether traditional *in situ* conservation efforts are enough to secure the genetic resources against future challenges, including climate change and pests and diseases. Cryo preservation and assisted migration have been mentioned as additional measures for some genetic resources at stake.

The question on how to proceed and make the work as resilient as possible for the future, needs to be discussed at a Nordic and European scale.

This document has been developed by the NordGen Forest Working Group on Genetic Resources, together with the secretariat of NordGen Forest .

1. Introduction

1.1. Why conservation of forest genetic resources?

Forest genetic resources are valuable at many levels and are critical for the long-term forest sustainability in a changing climate. Consequently, the present and future human use of the ecosystem services provided by forests depends on the genetic resources.

The key objective of genetic conservation is to maintain the adaptive diversity of forest tree populations. The genetic diversity ensures that forest trees survive, adapt and evolve under changing environmental conditions. Genetic diversity does also provide resilience to pests and diseases, thus maintaining forest vitality. Ultimately, the forest genetic diversity is the foundation for biological diversity at both species and ecosystem levels (de Vries *et al*., 2015; Koskela *et al*., 2007).

Forest genetic resources (FGR) are defined by The Food and Agricultural Organization of the United Nations (FAO) as "the heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific or societal value" (FAO, 2014b, p. 4). Through the Global Plan of Action for Conservation, Sustainable Use and Development of Forest Genetic Resources (2014a), FAO highlights the need for conservation and sustainable use of FGR. The importance of conservation of FGR is widely recognized and efforts are needed on the national, Nordic, European and global level.

The European Forest Genetic Resources programme (EUFORGEN) contributes to the implementation of regional-level strategic priorities in the Global Plan of Action (Kelleher *et al*, 2015). The Nordic countries are responsible for national-level activities, thus implementing the FAO Global

Plan of Action and the work of EUFORGEN. The aim of this report is to highlight the forest gene conservation work in the five Nordic countries, how the conservation of forest genetic resources (FGR) is implemented, as well as strengths and recommendations for further work ahead.

1.1.1. Northern edges of species distribution

Since the Nordic countries represent the northern leading edge of distribution for many temperate tree species, and core distribution areas for some cold tolerant boreal species (e.g. Norway spruce and Scots pine), this region may be particularly interesting for conserving FGR.

At the peripheral edges of a species range there are often unusual local adaptation processes leading to valuable evolutionary potential. The leading edge is likely to consist of relatively few individuals representing only a fraction of the population, leading to a narrowing in the genetic diversity. Still, it is the leading edge that will be the source of migration into new areas, e.g. under climate change (Fady *et al*, 2016), and it is thus very important to conserve sufficient amount of genetic diversity for future adaptability.

Changes in the environmental conditions and subsequent changes in the distribution range are not the only threats forests may face. Fragmentation, habitat destruction, pollution, poor silvicultural practices and poorly adapted forest reproductive material are among the main threats to forest tree populations (Koskela *et al*., 2007).

1.2. Conservation practices; *in situ*, *ex situ*, static and dynamic conservation

Conservation of forest genetic resources is carried out in the natural habitats or in artificially established collections outside the natural habitat. The ecological and biological variables and the species' reproductive biology, colonisation habits and competitive ability determines which method is most appropriate for conservation of FGR (Koskela *et al*., 2007).

Several methods for conservation are in use in the Nordic countries. Both geography, climate, management practices and policies are factors making differences in species distribution and composition, thus also in the implementation of the conservation strategies:

In situ conservation refers to conservation of populations of species in their natural surroundings. As for domesticated or cultivated species, this means conservation of populations in the surroundings in which they have developed their distinctive properties (FAO, 2014b). This type of gene conservation is often implemented in areas of undisturbed natural forest or naturally regenerated commercial forest. A representative forest area is normally set aside to serve as a gene conservation unit, e.g. the genetic reserves established in already protected forest areas in Norway, and the *in situ* conservation carried out in the state forest in Denmark.

The silviculture in such conservation areas is directed towards the support of natural regeneration. Potential threats and the ecological and economical value of the tree species or population are factors determinative for the level of silviculture carried out in the forest tree population (Kelleher *et al*, 2015).

Ex situ conservation is defined as "the conservation of components of biological diversity outside of the natural habitat of the target species" (FAO, 2014b). This type of conservation is carried out as seed orchards or clonal archives in tree breeding programmes, *ex situ* gene conservation stands, seed and pollen banks, *in vitro* storage or DNA storage.

Ex situ conservation is often viewed as a complementary method when *in situ* conservation of FGR is no longer possible due to threats such as changes in the local climate (FAO, 2014b). *Ex situ* may also be appropriate when a species is rare, the populations are fragmented in small patches, or when the regeneration is uncertain (Koskela et al., 2007). *Ex situ* conservation is also used in breeding programmes for introduced species. In Finland, species with high ecological and modest economic value, growing in smaller patches are conserved in tree collections based on material collected from several stands. There will be natural changes in the genetic structure in such *ex situ* collections once they are established, and therefore this type of conservation is called dynamic *ex situ*.

Evolutionary or dynamic conservation refers to a "natural system in which the evolutionary forces and natural selective processes which gave rise to diversity are allowed to operate and over time modify allelic frequencies" (FAO, 2014b, p. 7). In dynamic *in situ* conservation units, evolutionary processes as natural selection and co-adaptation, allow the species or populations to adapt and evolve alongside the changes in the local climate and evolution happening outside the conservation units (FAO, 2014b). The minimum requirements for conservation units in EUFGIS, as explained in Table/box number page 13, are developed to ensure dynamic conservation of the genetic resources.

Dynamic conservation can also take place in *ex situ* stands, in cases where natural selection and regeneration happen in e.g. planted sites without intervention from humans. When a rapidly changing climate is threatening *in situ* conservation areas, dynamic *ex situ* conservation can be a substitute for *in situ* conservation (Kelleher *et al*, 2015).

Static conservation on the other hand involves conserving the individual genotypes. Examples of static *ex situ* conservation could be grafted clonal archives, long-term seed storage and cryopreservation. As the threats to FGR are increasing with rapid changes in land use and climate, long-term seed storage might become increasingly relevant also for FGR, to support dynamic conservation (FAO, 2014b).

1.2.1. European information system for dynamic conservation of FGR

EUFORGENs Pan-European strategy for genetic conservation of forest trees states that "To ensure the adaptability of tree populations in the future, efforts should be made to conserve a sizeable amount of the adaptive genetic variation that currently exists in the European tree populations" (de Vries *et al*., 2015, p. 6). The strategy aims to maintain the evolutionary potential of European forest tree species throughout their entire distribution ranges.

As neither forest tree populations nor their threats are limited by national borders, successful conservation of FGR depends on cooperation across borders.

Forest tree species are assumed to be adapted to the prevailing local environmental conditions. Therefore, to embrace as much as possible of the genetic diversity, the Pan-European work on conservation of forest trees aims among other efforts to distribute *in situ* conservation areas within different climatic zones, using the zones as a proxy for adaptive diversity. For simplicity, EUFORGEN has established an aggregated system with 8 climatic zones covering the whole of Europe. For each country, and from a Pan-European perspective, a sufficient level of adaptive variation is suggested to be captured by establishing conservation units in all climatic zones within the species' distribution range (de Vries *et al.*, 2015). Nordic countries cover four zones. European efforts are at the same time working on developing better climatic stratification for Europe that probably will be implemented in the future.

EUFORGEN develops and maintains the online information system EUFGIS. The EUFGIS portal is a tool for maintaining information on a Pan-European network of dynamic *in situ* and *ex situ* conservation units of forest trees. EUFGIS serves as a support to the European countries in their effort to implement FGR conservation as a part of sustainable forest management, and currently contains information about 3 591 conservation units and 107 tree species in 35 European countries. The units harbour a total of 4 314 tree populations. (EUFORGEN, 2019).

All units in EUFGIS must fulfil the jointly agreed minimum requirements (Koskela *et al*, 2013), which also makes EUFGIS a trustable source of harmonized data for international reporting and monitoring.

Minimum requirements for conservation units in EUFGIS

A conservation unit must have:

1. A designated status as conservation area of forest trees and a management plan in which genetic conservation of forest trees is recognised as a major management goal.

2. One or more target tree species, each subject to one of the following conservation objectives:

   a) to maintain genetic diversity in large tree populations
   b) to conserve specific adaptive or other traits in marginal or scattered tree populations
   c) to conserve rare or endangered tree species with populations consisting of a small number of remaining individuals.

3. A minimum population size of each target tree species, which depends on the conservation objective (1-3).

4. Means for management when needed, to ensure the continued existence of target tree populations and create favourable conditions for growth and vitality of the target tree species and their natural regeneration.

5. Means for monitoring, consisting of regular visits and field inventories.

Source: Koskela *et al*, 2013

Gaps in the conservation efforts on a European level were identified by de Vries *et al*. (2015) by linking species distributions of 14 pilot tree species and location of conservation units to the climatic zones. According to the registrations in EUFGIS at that time, these species lacked conservation units in about 74 % of the combinations of country and climatic zone on average (de Vries *et al*., 2015, Table 6). The strategy states that countries should establish new units in areas (species or climatic zones) identified as gaps. This is an ongoing process.

The long term goal is to include the genetic resources of all native species in the conservation programmes. Several tree species are currently conserved across the Nordic countries (Table 1).

Table 1: Number of conservation units registered in the EUFGIS portal for the Nordic countries (per 08 February 2019). Some units may contain more than one target species. Species without any units in EUFGIS are not shown.

	Denmark	Finland	Iceland	Norway	Sweden	Total
Field maple *Acer campestre*	5					5
Norway maple *Acer platanoides*	6	4		2	3	15

Black alder *Alnus glutinosa*	15				25	40
Grey alder *Alnus incana*					10	10
Silver birch *Betula pendula*	12	5			8	25
Downy birch *Betula pubescens*	11	8	1		23	43
European hornbeam *Carpinus betulus*	10				11	21
Common hazel *Corylus avellana*					9	9
European beech *Fagus sylvatica*	13			2	40	55
Glossy buckthorn *Frangula alnus*	15					
Common ash *Fraxinus excelsior*	12	5		3	20	40
Common holly *Ilex aquifolium*				3		3
Common juniper *Juniperus communis*					1	1
Wild apple *Malus sylvestris*	15					15
Norway spruce *Picea abies*		11		5	190	206
Mountain pine *Pinus mugo*[1]	1					
Scots pine *Pinus sylvestris*		22			116	138
Eurasian aspen *Populus tremula*	16				53	69
Wild cherry *Prunus avium*	15				5	20

Cherry plum *Prunus cerasifera*[1]	2					
Bird cherry *Prunus padus*	7				2	9
Sessile oak *Quercus petraea*	9			2	12	23
English oak *Quercus robur*	14	2		3	43	62
Goat willow *Salix caprea*					9	9
Rowan *Sorbus aucuparia*	25				2	27
Swedish white-beam *Sorbus intermedia*	3					
Wild service tree *Sorbus torminalis*	1					
Common yew *Taxus baccata*				3		3
Small-leaved lime *Tilia cordata*	5	5		3	16	29
Large-leaved lime *Tilia platyphyllos*	1					
Wych elm *Ulmus glabra*	8	1		4	9	22
European white elm *Ulmus laevis*		2				2

[1] *Non-native tree species in the Nordic countries.*

2. The Nordic countries – state of the art

Both *in situ* and *ex situ* conservation are used in all Nordic countries. A description of the conservation strategies in each country follows below. The reason for gene conservation varies among the countries, from focus on commercial species to focus on rare species.

In the sub chapters below, emphasis is put on conservation registered in EUFGIS, as it consists of harmonised data which is therefore comparable across countries and fulfil defined criteria. The EUFGIS database only pertains to dynamic conservation but includes both *in situ* and *ex situ* conservation units.

Other types of gene conservation, not accounted for in the EUFGIS system, will be addressed for some countries, but not in a systematic comparative way and the level of detail may vary among the countries.

2.1. Overall status of *in situ* conservation in the Nordic countries

In total the Nordic countries contain approximately 63 million hectares of forest land, which corresponds to 29 % of Europe's (Russia not included) 215 million hectares, and they have 19 % of Europe's wood stock. The bulk of this is in the three countries Sweden, Finland and Norway (Nordic Forest Research, 2017). In the Nordic region, one hectare grows at a rate of five cubic metres per year, on average.

The region has relatively low diversity of forest tree species. However, as previously stated, the Nordic distribution ranges for forest tree species may be particularly interesting for conserving FGR.

Based on the European work on gene conservation, an overview of conservation units and climatic zones in the northern part of Europe is given below (Fig. 1). Nordic countries cover four out of totally eight zones in Europe and the zone EG (cold and moist) is particularly well represented.

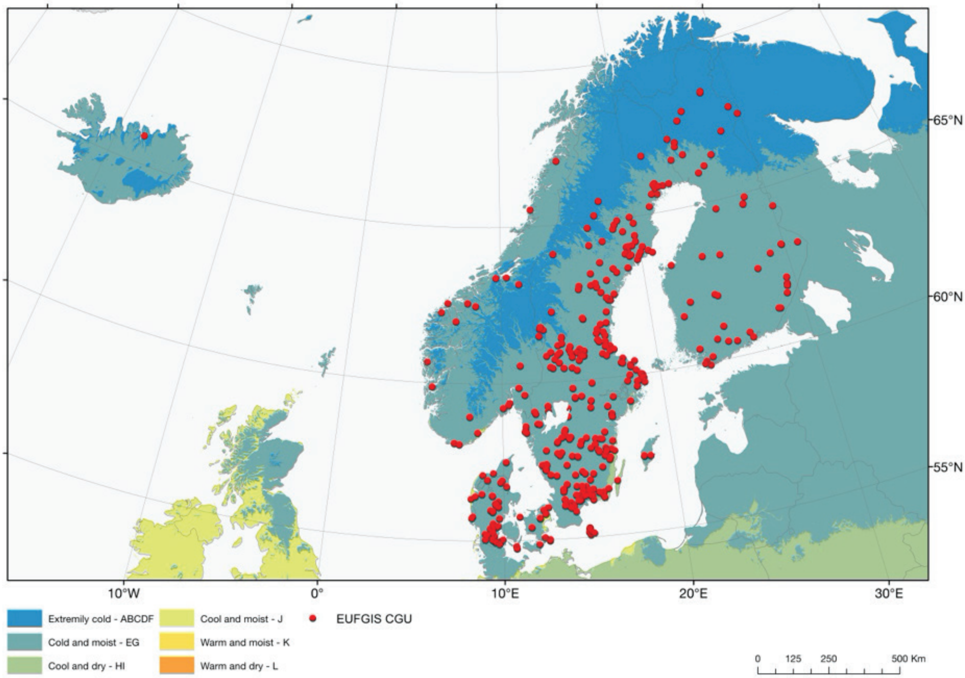

Figure 1 Conservation units and climatic zones registered in the EUFGIS. Aggregated climatic zones, based on the new environmental stratification developed by Metzger et al. (2013). Source: EUFORGEN, 2019

For work at national level and especially for the Nordic region, the climatic zones after de Vries *et al.* (2015) are very coarse and do not reflect the variation in the climate across the region. The Nordic region spans from 55 ˚ – 70 ˚ latitude comprising mainly two climatic zones; extremely cold, and cold and moist. The temperature and the photoperiod gradients which to a large degree control phenology are not at all reflected in these climatic zones.

Some Nordic countries have developed their own more detailed climatic zoning as basis for their national conservation programme. There may be good reasons for developing this in all countries, as basis for conservation. Synthesizing and developing climatic zones across the Nordic region reflecting the steep climatic gradients in the region, capturing both latitudinal and altitudinal variation, as well as variation between coastal and inland regions, should be prioritized at a Nordic level.

Work on conservation of forest genetic resources in the Nordic region is a national responsibility, supported by EUFORGEN and the Nordic cooperation. Table 2 gives an overview of current conservation practices, and differences among the countries in the way *in situ* conservation is implemented.

Table 2 The variation in the implementation of in situ *conservation among the Nordic countries*

	Denmark	Finland	Iceland	Norway	Sweden
Which species	Common species of trees and shrubs	Common species	Downy birch (*Betula pubescens*)	Vulnerable species and Norway spruce	All species
What kind of units	Specific and protected nature areas	Specific		In nature reserves	In habitat protection areas
Management	Depends on the specific area.	Regeneration supported. Commercial harvesting		Only in accordance with the nature reserves	Silviculture to support natural regeneration
Regeneration	Natural	Natural or with the stand´s own origin		Natural	Natural
Monitoring	Every 10th year (visit). Plans are renewed every 15th year.	Every 5 years (visit + forest planning systems)		Every 10 years	Visit every 8 years to assess if management is required

Ownership	The state	The state and commercial companies		Private and state	Private and state
Legal	Administrative protection (in some cases also stricter nature protection)	Voluntary agreements		The areas are protected by nature reserve law	Eternal agreement between state and forest owner

As evident from Table 2, there is much variation among the Nordic countries in the number of species conserved and the type of conservation used for the various species. Countries have made their own national priorities on which species to conserve and where to place e.g. the designated conservation units in the *in situ* network. Attached to this report is an overview of the current number of *in situ* conservation units per species. In total the genetic resources of 32 tree species are conserved in the Nordic countries, of which 16 are conserved both *in situ* and *ex situ*, and 17 are conserved in two or more climate zones across the region. Examples of conservation effort for species are given below.

Scots pine (*Pinus sylvestris*) is a boreal species with a continuous distribution across Fennoscandia. It is not naturally distributed in Denmark and Iceland. Scots pine is an economically and ecologically important species, with breeding programmes both in Sweden and Finland. In these countries we find many evenly distributed GCU units (Fig. 2A) for the species. Silver birch (*Betula pendula*), which also has a wide distribution across the Nordic region, has however a low number of GCU units (Fig. 2B). Also, across Europe, there are very few GCU units for this species.

How many GCU units are necessary to conserve species genetic resources, and how should they be distributed across the range to cover the total? Across the Nordic region, countries may complement each other in effort, especially on widely and continuously distributed species, but it is still important to gather knowledge about the species genetic variation and structure to evaluate the status and in a systematic way identify gaps and priorities.

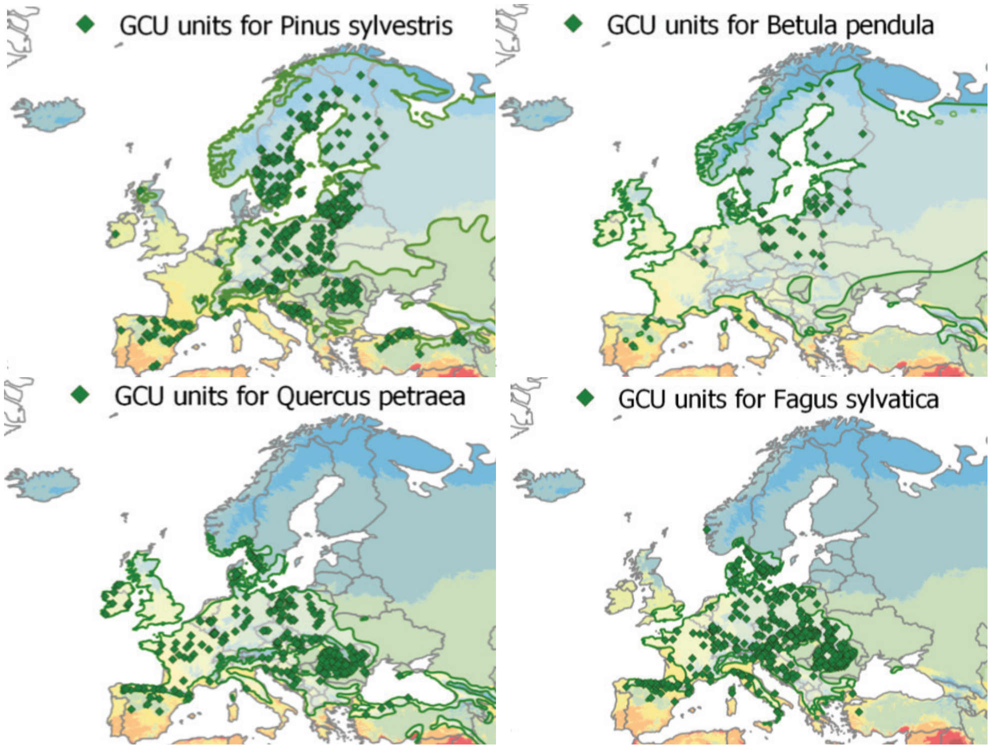

Figure 2. Distribution range and designated in situ conservation units (GCUs) for Pinus sylvestris *(A)*, Betula pendula *(B)*, Quercus petraea *(C) and* Fagus sylvatica *(D).*

Due to climate change, temperate species, which have their northern edge of distribution in the Nordic countries, like sessile oak (*Quercus petraea*) and beech (*Fagus sylvatica*) (Fig. 2C and 2D), may expand their distribution in the north (Kramer et al. 2010, Stojnic et al. 2018, but see Garate – Escamilla et al. 2019). The distribution ranges of these species are very limited in the Nordic region and there are very few designated GCU units, although densely selected in Sweden (Fig. 2C and 2D).

As the leading northern distribution edges in these species may become important in the future, a careful evaluation of their genetic resources and conservation status should be done to secure sufficiently genetic diversity for evolutionary adaptability.

2.2. How to evaluate and describe the status of the *in situ* network

Hitherto, there has been no systematic evaluation of how the GCU units cover the species genetic diversity in the European programme. To further evaluate and to identify conservation gaps, one way could be to add layers of information and see how the GCUs cover not only different climatic zones, but also genetic diversity present in the species. In this chapter, we present some ideas on how to evaluate the conservation status for two different species, common ash and Norway spruce, focusing on the Nordic countries, using published and available molecular genetic data we had at hand.

Common ash (*Fraxinus excelsior*) (Fig. 3) is a temperate species. The natural range of the tree covers most of Europe and it has its northernmost distribution in the southern parts of the Nordic region (Fig. 3). After the ice age, it colonized the Nordic countries (Fennoscandia) from south-eastern Europe. The colonization process of the northern range lead to differentiation among populations and a pronounced loss of diversity, especially along the Norwegian coast (Tollefsrud *et a*l. 2016).

Norway spruce (*Picea abies*) (Fig. 4 and 5) is one of the most important commercial tree species in Europe. It is a boreal cold tolerant species, with a northern and a southern distribution range. The northern range compromises large parts of Finland, Sweden and Norway. Colonization of Fennoscandia took place along a northern and a southern migration route from refugia on the East European Plains and diversity was largely maintaining during colonization (Tollefsrud et al. 2008; 2009). Genetic variation was possibly even supplemented by a high latitude refugia along the Atlantic coast of Norway (Parducci *et al*. 2012).

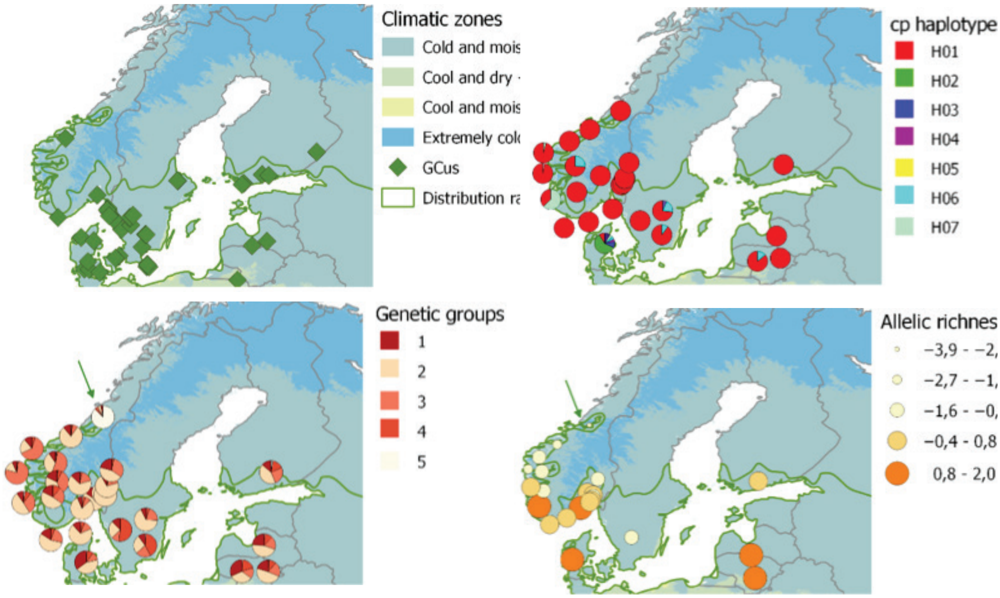

Figure 3. Tentatively evaluation of how GCU units for Fraxinus excelsior *cover; (A) the different climatic zones, (B) phylogeographic groups represented by chloroplast haplotypes, and (C) genetic groups inferred from nuclear microsatellites analysis. Pie charts show the probability of individuals in a population to be assigned to one of the five genetic STRUCTURE groups (data from Tollefsrud* et al. *2016). Fig. D show the distribution of allelic richness based on nuclear microsatellite data from Tollefsrud* et al. *2016, plotted as deviation from the mean illustrated using different colours and symbol sizes.*

For common ash, it seems that the existing GCU units in Sweden, Denmark and Finland cover both the whole distribution, the present climatic zone (cold and moist), as well as the two most common phylogeographic groups quite well (Fig. 3B). In Norway, on the other hand, there are three GCU units, which poorly cover the differentiation among the populations on the west-coast as revealed by nuclear microsatellites illustrated in Fig. 2C. Based on the available information (Fig. 3B, C and D) we can identify regions of genetic differentiation and diversity that can be valuable to conserve. In Norway for instance, additional GCUs should cover the two forests on the southern cost where allelic richness is very high, as well as the differentiation present along the west-coast (Fig. 3C).

It is also interesting to see that the screened population in Denmark seems to harbour very high levels of genetic diversity, a region that seems to be covered by a GCU unit already. Notably, in Fig. 3B, we have plotted all the GCU units in the EUFGIS database, i.e. also GCU units that are *ex situ*. For instance, in Finland, only one of the GCU units are *in situ*, the rest, including the one outside the distribution area are *ex situ*. For a thorough evaluation, one needs to consider which GCU units are in situ and which are *ex situ* collections and how they may complement each other covering the existing diversity in the natural distribution range of the species.

For ash, which is threatened by ash dieback, inventories on health status would be valuable to add as a parameter for selecting GCUs. Another important layer could be differentiation in adaptive traits such as timing of bud flush and bud set. How these traits vary along climatic gradients is not well described, and should be further investigated, to make sure we capture also this type of phenotypic variation in the *in situ* network.

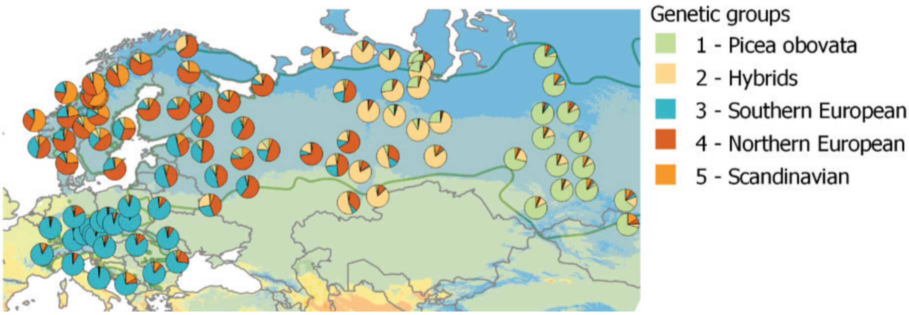

Figure 4. Illustration of different genetic groups in Picea abies *and* P. obovate *as inferred from nuclear microsatellites analysis. In its northern range,* Picea abies *forms a large continuum from the western coast of Norway eastwards to the Ural Mountains.* P. obovata *is found mainly east of the Siberian River Ob and a large hybridization zone west of the Ural Mountains (Fig. 4) differentiate between the two species (Tsuda* et al*. 2016).* P. abies *and* P. obovata *diverged from each other approximately 18 million years ago (Chen et al. 2019). Pie charts show the probability of individuals in a population to be assigned to one of five genetic STRUCTURE groups (Figure reproduced after Tsuda* et al*. 2016).*

Norway spruce has a northern and a southern distribution range which diverged from each other approximately 15 million years ago (Chen et al. 2019). The present-day distribution of genetic variation in spruce is a result of complex population movements and admixture events among the different gene pools (Fig. 4). In addition, the planting of foreign provenances has also largely influenced the genetic resources we are using today, e.g. in the breeding programmes (Chen et al. 2019).

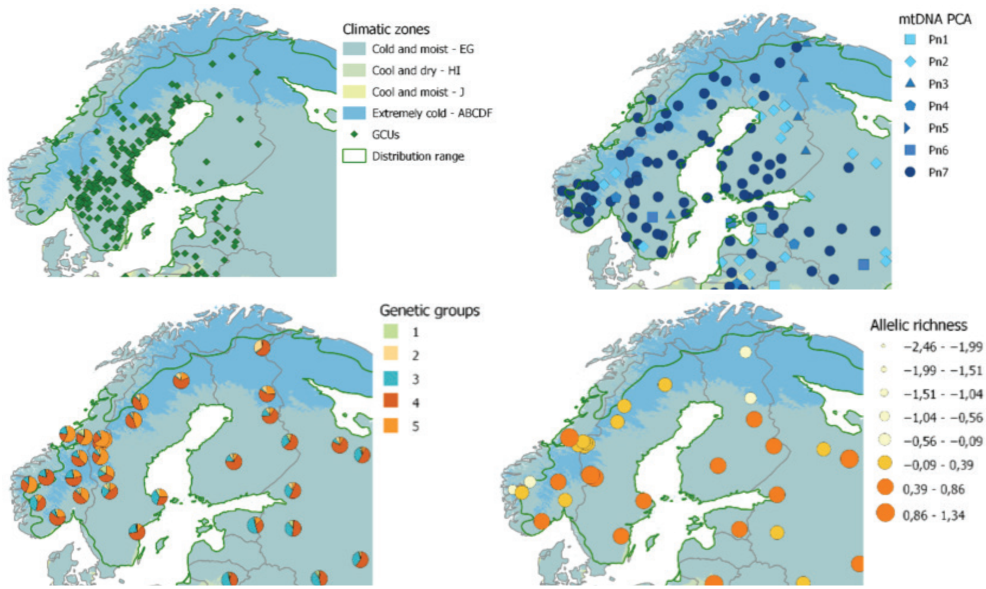

Figure 5. Tentatively evaluation of how GCU units for Picea abies *cover; (A) the different climatic zones, (B) phylogeographic groups represented by mitochondrial (mtDNA) data from Tollefsrud* et al. *2008, and (C) genetic groups inferred from nuclear microsatellites analysis (as shown in Figure 3) from Tsuda* et al*. 2016. (D) Distribution of allelic richness based on nuclear microsatellite data from Tsuda* et al*. 2016, plotted as deviation from the mean illustrated using different colours and symbol sizes.*

The distribution range of Norway spruce covers three climatic zones in the Nordic countries, cold and moist, cool and moist and extremely cold (Fig. 2A). There is an obvious uneven distribution of GCU units across the Nordic countries with a very dense distribution in Sweden, medium dense in Finland and very scattered distribution in Norway.

By comparing Fig. 5A with 5B and 5C, we can evaluate how well the GCUs cover the different genetic groups for P. abies. The dense distribution of GCUs in Sweden covers the genetic diversity very well. In Finland, the phylogeographic groups present are all captured by the distribution of the GCU units (fig 5B). The Finnish GCU units also seem to cover the genetic diversity based on nuclear microsatellites (Fig. 5C and D). In Norway, the GCU units does not cover all the phylogeographic groups present in southern Norway (Fig. 5B). Additional GCU units could thus be added here. Based on nuclear microsatellite analysis, a genetically differentiated group stands out in the region of Trøndelag (Fig. 5B). This region has also been shown to harbour high frequencies of the ice age variant in accordance with results from Parducci et al. (2012), as mentioned above. Allelic diversity is also very high in the region (Fig. 5D). There is one GCU unit established for Norway spruce here (Fig. 5C and D).

The examples of common ash and Norway spruce above shows that data already exists for some species, for more targeted conservation in the Nordic region. In the future, gathering more available data on e.g. the level of differentiation and allelic richness (as shown in fig. 2D), could provide a better background in selecting units to conserve. Other important parameters, like e.g. phenotypic diversity, could also be included. For instance, Norway spruce show strong clinal variation in traits important to climate adaptation and growth, variation that is captured by seed zones and breeding zones (Fig. 6). By combining layers of both climatic zones, available molecular data, as well as seed zones or breeding zones, regions for future GCU units can be identified to conserve as much genetic diversity as necessary in several species.

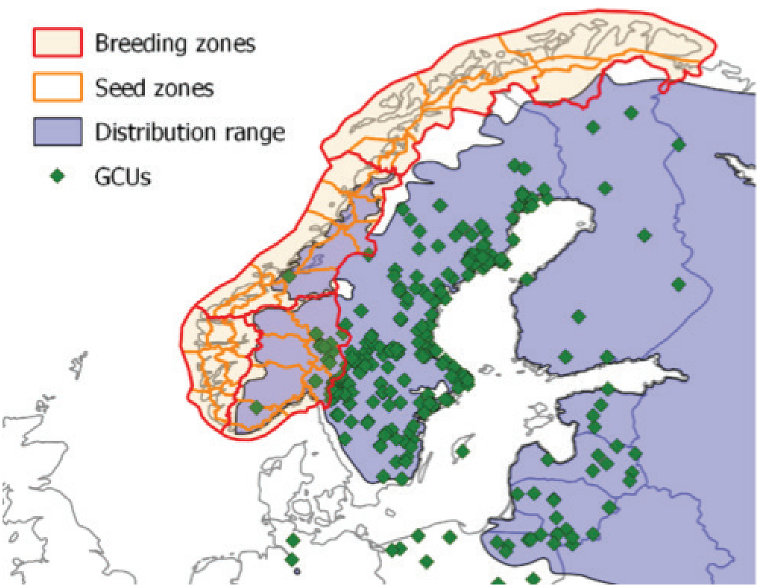

Figure 6. Distribution range of P. abies *with GCU units and breeding zones and seed zones for Norway.*

In the following chapters, you will find more detailed info about national work on genetic resource management within the Nordic region.

2.3. Denmark

In 2015 the total forested area in Denmark covered 14.5 % of the country, and the area is increasing. The most abundant species are Norway spruce (*Picea abies*), beech (*Fagus sylvatica*), pine species (*Pinus*) and oak species (*Quercus*). In forestry, species and provenances have been imported from many countries.

The Danish gene conservation strategy for trees and shrubs is from 1994. The Danish Nature Agency has implemented the strategy on state owned forest areas, and the distribution of conservation units is thus dependent on the distribution of state forest. Seven gene-ecological zones make the basis for the in situ conservation and state forest is to some extent present in all zones. Having the units in the state forest makes it possible to implement the necessary restrictions and to ensure conservation in the long term. The main objectives are to conserve the genetic variation, act as a buffer for climatic and environmental changes and provide a basis for future breeding programmes. Conservation of genetic variation of trees and shrubs is also a part of the Danish biodiversity strategy (Graudal *et al.* 1995).

In situ conservation is the preferred method for conservation of native species. Introduced species are conserved *ex situ*, which also to some extent is a method used for native species.

56 native species (trees and shrubs) are conserved in situ in 89 units covering 2 880 hectares. Several species are conserved in the same unit, as each species is represented at 1-28 different sites. A forest tree is typically represented in 8-15 sites. The units are often in areas under other kinds of protection, e.g. nature conservation.

The areas have guidelines which emphasize natural regeneration and isolation zones. Natural regeneration is preferred in order to give a dynamic conservation, where the genetic variation gradually is changing, reflecting changes in the environment and random events. The isolation zones are aiming at reducing gene flow of other origin. The designation "*In situ*-protection” is implemented in the operative plans for the state forests. In the EUFGIS database there are 72 *in situ* units registered from Denmark. In general, the minimum requirements are met.

The *ex situ* conservation includes 53 introduced and native species covering 1 200 ha. It consists of state owned seed sources. All together 98 seed stands and seed orchards are included. Also, clonal archives from the breeding programmes are part of the conservation. The introduced conifers are important commercial species and are a part of different breeding programmes. The programmes often include clonal archives, which serve as *ex situ* conservation units as well as contribute to the breeding programmes. The stands and sites in the breeding programmes are managed for seed production, and are implemented in the operative plans for the state forest. But no regeneration plans are implemented. This means that the conservation is temporary and faced with the question of regeneration at the end of every rotation.

2.4. Finland

73 % of the land area in Finland is covered by forests, which makes Finland the most forested land in Europe. There are 19 tree species that are regarded as native and in addition to these, Siberian larch (*Larix sibirica*) and hybrid aspen (*Populus tremula x tremuloides*) are accepted for forestry use. The most abundant species are Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). The share of deciduous trees is about 20 %, of which silver birch and downy birch (*Betula pendula and B. pubescens*) are the main species.

Genetic conservation of forest trees started in Finland in 1992 with the selection of the first gene reserve forest. The first programme on plant genetic resources in agriculture and forestry started in 2003. A new gene conservation programme covering agricultural plants, forest trees, farm animals and fish was launched in 2018. The Natural Resource Institute (Luke) is responsible for the coordination of the programme and implements it together with several stakeholders. The most important partner in forest genetic conservation is the national forest service Metsähallitus together with several private forest companies that have a gene reserve forest on their land.

The main objective of gene conservation is to conserve genetic variability within each species. In situ conservation in gene reserve forests is the principal method for wide spread and common species which are (often) commercially important. The *in situ* conservation stands represent the genetic origin and variability which has not been influenced by breeding to a large extent. There are currently 44 *in situ* gene reserves covering about 7 000 hectares. The target species in the gene reserves are 2 conifers and 6 different deciduous species. Conservation status is based on voluntary agreements with private companies or the state forest. They are managed as regular forests, but are always regenerated with the original genetic material, either naturally or artificially and management is targeted in supporting regeneration. A seed bank for coniferous gene reserve forests has been established for regeneration purposes and also for genetic studies. So far it covers half of the *in situ* units of conifers. Some of the seed bank seed lots where deposited as a back-up in Svalbard Global Seed Vault in 2015.

In Finland, dynamic *ex situ* conservation in collections of living trees is the principal method for rare species which grow scattered or in small stands. Typically, the species are not used extensively in forestry, but they may have high value in ecosystems and landscape. The *ex situ* units are established with material collected from numerous natural stands either with seedlings or grafts. The main goal is to conserve the natural genetic variability but the collections are also expected to produce seed which will be adapted to Finnish conditions but genetically more variable than seed from very small natural stands. However, this reproductive material will not be bred since no selection for traits other than health has been made. Finland has *ex situ* collections of 6 broadleaf species, where 4 out of 6 also are target species in gene reserve forests.

2.5. Iceland

In the Icelandic forested area, there are 10 native species, including both trees and shrubs. In addition, about 640 species have been included in experiments testing for their usability, 19 species have shown an acceptable adaptation. Downy birch (*Betula pubescens*) was the most planted species in 2010-2013, and is together with rowan (*Sorbus aucuparia*) the only native species planted for forestry. It is however uncertain whether all the plant material of rowan originates from Iceland, since the importation of seeds have been frequent and widespread. Sitka spruce (*Picea sitchensis*), Siberian larch (*Larix sibirica*), lodgepole pine (*Pinus contorta*) and black cottonwood (*Populus balsamifera ssp. trichocarpa*) are four other commercial important species.

An inventory of the Icelandic birch forest was completed in 2014, and all natural or semi-natural stands are now known and mapped. The area with natural birch forest is increasing, but the future expansion will depend on changes in the climate and land use, as grazing by sheep is preventing the spreading. There is one *in situ* conservation unit for birch (*Betula pubescens*) which is in Skuggabjörg, North Iceland, registered in the EUFGIS database. Another important conservation unit for birch is Bæjarstaður in South-East Iceland. Bæjarstaður has been the most planted provenance in Iceland for a long time. Breeding material of birch, named Embla, is mostly based on parent material originated from Bæjarstaður. Nine provenance trials including 50 provenances have been established across the country. These are mainly established for breeding purposes, but might be used as *ex situ* conservation units in the future.

The distribution of rowan stands is currently not known, and they often appear as single trees in birch forest stands. Recently they are found more often in new larch forest stands, most likely spread from gardens and shelterbelts. In forestry both Icelandic and Danish sources have been used, which pose difficulties if one would like to find the origin of the trees spread from planted stands in the future. There is no ongoing systematic conservation in rowan, but selection of plus trees has been made for breeding, and progeny testing is ongoing. Inventory of rowan in Iceland will be carried out during next two years to get a better platform for efficient conservation strategy.

To date, eight natural clones of aspen (*Populus tremula*) have been discovered, as well as three clones of Danish origin. The natural clones are found on private properties and most of them have been vegetatively propagated by tissue culture and are today conserved *ex situ* in clonal archives. Most of the original clones are in areas with little or no pressure from grazing animals.

Exotic tree species used in the forestry are preserved in provenance trials, clonal tests and archives or seed orchards. A strategy on how to conserve the genetic variation of introduced species is to be made in the future. Old provenance trials can be thinned to preserve maximum genetic variation. Other alternatives are thinning to preserve the best genetic material as possible breeding population for the future or thin it for temporary seed production.

2.6. Norway

Forests and wooded land cover 38 % of the land area of Norway. Norway spruce, pine and birch are the most common and commercially important species. Apart from spruce, these are however not the main species targeted for genetic conservation.

The national programme on forest genetic resources was established in 2001 and is now administered by the Norwegian Genetic Resource Centre. A committee on forest genetic resources has until December 2019 been acting as an adviser for the targeted work. The genetic resource centre, close collaboration with key partners, dedicated genetic resources funds (managed by the Norwegian Agriculture Agency), and a database with updated information about all protected areas in forests with full species lists (kilden.nibio.no), are all facilitating the conservation of forest genetic resources. The conservation of forest genetic resources has so far focused on non-commercial species and Norway spruce. The objective of the genetic resources conservation is to conserve genetic diversity and adaptability for the future facing climate change.

A national strategy[2] for the conservation and sustainable use of genetic resources for food and agriculture, including farm animals, plants and forest genetic resources, was released in December 2019.

In situ conservation of genetic resources of forest tree species is done in nature reserves. 23 gene conservation units in such reserves have since 2008 been identified and included in the European database EUFGIS, including nine deciduous species and Norway spruce. The selection of species for conservation is based on an evaluation of vulnerability of forest genetic resources (Myking, 2002). Norway spruce is included in the *in situ*

[2] https://www.regjeringen.no/contentassets/3f5ee035363b44b6b57fe0a2f676ad15/strategi-forrad-av-gener--muligheter-og-beredskap.pdf

conservation to preserve a genetic reference to the material in the breeding population.

The genetic resources in the genetic conservation units are indirectly protected by law through the restrictions of the nature reserves. The areas are managed according to the restrictions given in the protected areas, which in most cases means that silviculture is restricted. The aim is that the conservation units will be monitored with 10-year intervals.

In the newly published plan for conservation of FGR in Norway, and in accordance with the Pan-European strategy for genetic conservation of forest trees, some additional marginal tree species, such as Wild apple (*Malus sylvestris*) and *Sorbus* species, as well as more of the widespread species, are proposed for the *in situ* conservation programme (Fjellstad, 2019).

Since 2018, dynamic *ex situ* conservation has been established in 8 planted spruce stands in Eastern Norway, in cooperation between the Norwegian Genetic Resource Centre, The Norwegian Forest Seed Centre and forest owners. The aim is to conserve genetic material from the original plus tree selection for breeding. The stands will be managed for regular forestry and regenerated with seed collected in the respective stands after harvest.

Apart from the newly established efforts on dynamic *ex situ* conservation, *ex situ* conservation in Norway is performed in long-term tests of clones, families and provenances in research plantations, in progeny tests, clonal archives and seed orchards belonging to the national breeding programme and storage of seed lots for forest regeneration managed by the Norwegian Forest Seed Centre. Some seed lots of Norway spruce and pine are since 2015 deposited and stored as a back-up in Svalbard Global Seed Vault.

2.7. Sweden

About 22.8 million hectares, corresponding to 56 % of the total land area in Sweden, is productive forest land. The major forest trees are Norway spruce (*Picea abies*) (42 % of the total standing volume), Scots pine (*Pinus sylvestris*) (39%) and birch (*Betula spp*.) (12 %). Other native and alien species occur at considerably lower proportions. For instance, the most common native broadleaves, oak (*Quercus spp.*), Eurasian aspen (*Populus *tremula*) and alder (*Alnus spp*.), together make up for 4.4 % of the productive forest area.

Gene conservation is performed in two separate programmes. In one programme, the Swedish Forest Agency, Skogsstyrelsen is responsible for dynamic *in situ* gene conservation of native tree species in autochthonous stands. The other program is an *ex situ* programme within the conventional breeding programme for the three major tree species in Sweden organized by Skogforsk. One of the objectives in the breeding programme is long-term management of the genetic resources as well as improvement of tree performance and preparation for future climatic change. A future possibility is a combination of both to facilitate both breeding and gene conservation, for example in assisted migration using shorter generation cycles than in a traditional gene conservation programme.

The main national policies embodying the conservation and use of genetic resources includes the environmental quality objective Sustainable Forests and the forest policy environmental goal.

The Swedish Forest Agency's strategy for gene conservation (from 2014) is in line both with national and international policies. As described in this strategy, gene resources are conserved in habitat protection areas which are eternal agreements between the forest owner and the state. The strategy allows a resource efficient multi-conservation of habitats, species and forest gene resources within the same protected area. A minimum number of trees per species is required within a unit, and units should be evenly distributed across the country to capture more genetic variation.

Today, Sweden has more than 300 habitat protection areas with almost 500 conservation units (Black-Samuelsson *et al*., 2017), of which most have been reported to EUFGIS. In some areas more than one tree species is conserved. There is still a need for additional conservation units, mainly for red listed species such as elm (*Ulmus glabra*) and ash (*Fraxinus excelsior*), as well as for minor species as those occurring with their northern marginal populations in Sweden, e.g. sessile oak (*Quercus petraea*) and yew (*Taxus baccata*).

In Sweden today, the production of forest reproductive material is largely based on seed orchards with improved materials from breeding populations within the tree breeding programmes. Existing tree breeding programmes for native species are managed by Skogforsk for the main species. In the breeding programme, several thousand plus-tree trees with vast distributions have been collected and grafted to breeding *ex situ* archives with a high population genetic diversity. To manage inbreeding at an acceptable level over time and to secure a sustainable breeding as well as a sufficient level of long-term conservation, the breeding is done in a meta-population within each species.

There are also seed orchards for common oak (*Quercus robur*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), lime (*Tilia cordata*), maple (*Acer platanoides*) and wild cherry (*Prunus avium*). The plantation trees are phenotypically selected for primarily high vitality (health) and stem and branch quality, but also for growth. The purpose of seed orchards is both seed production for practical forestry and gene conservation. They also make up base materials for possible breeding in the future.

3.1. Added value of the Nordic forest gene resource conservation

The most important reason for conservation of forest genetic resources is to secure enough genetic variation to make the species resilient and able to adapt to future challenges such as climate change, and to serve as basis for future development and use. The Nordic conservation efforts already in place apply mostly to widespread and often commercially important species and genetic resources, but there is also conservation of rare species and species with their northern edge of distribution in the Nordic countries.

The commitments to implement the FAO Global Plan of action and the EUFORGEN Pan-European strategy for genetic conservation of forest trees lie at the national level. It is evident that the countries in the Nordic region do support and complement each other with regard to conserving genetic diversity across climatic zones. There is however still work to do to fully comply with the Pan-European strategy, to conserve all species in climatic zones across countries.

3. Discussion

3.2. Strengths and challenges

3.2.1. Formalization of gene conservation

In all the Nordic countries, there is a general acceptance of the importance of forest genetic resources and a will to secure these in accordance with international obligations. All the countries have national goals for the conservation of genetic resources. This is furthermore underlined by the fact that all countries are taking active part in the work of the Nordic Genetic Resources Centre, and in the European work on genetic resources within EUFORGEN. As described in chapter 2, the conservation activities are organised differently and challenges vary from country to country.

One challenge is the long-term perspective of gene conservation. Formalisation for long-term conservation may differ among countries and the conservation units for genetic resources may lack a formal legal status. This has proved to pose some difficulties with regard to proper management of the stands, and the allocation of necessary funds for the work. The existing conservation units, for instance in Norway, are protected by law as nature reserves. As long as there is a good dialogue between the agricultural sector responsible for protecting the genetic resources, and the environmental sector, responsible for the nature reserves, this is regarded as a good way for long-term protection. But there is still a need to secure necessary management of the nature reserves, to secure regeneration of the genetic resources and to avoid other species taking over. Lack of legal status of the units, may also weaken the communication and public acceptance of the conservation work.

In Sweden, work on *in situ* protection has increased at a very high rate during the last couple of years, resulting in conservation units in habitat protection for most of the native species. It has nevertheless proved difficult to establish habitat protection areas for minor and red listed species, as these species generally require larger protected areas, such as nature reserves, to include enough diversity. This issue is still not settled.

The effectiveness of the gene conservation work in each country is dependent on its administrative organisation. In some countries all the work is held by the agricultural sector, whereas in other countries the work is dependent on the cooperation between agricultural or forestry and environmental sectors. The latter could make the work to some extent more bureaucratic and more resource consumptive. On the other hand, this makes it possible to communicate the importance of the work across sectors, and to work jointly on some of the challenges.

3.2.2. Management and conservation in the long run

The gene conservation strategies in the Nordic countries are national strategies, aiming at fulfilling national priorities and at the same time fulfilling international obligations. But how is the conservation in a long-term international perspective and under climate change?

The *in situ* approach has the intrinsic quality that the genetic resources are viable under the current environmental conditions. It also makes an assumption that the species and the present genetic variation will be able to survive and evolve at the site in the long run. Climate change might challenge this, either by shifting the distribution range of the species or by fast changes causing strong selection pressure reducing the genetic variation. This can even be intensified if gene flow to the *in situ* gene conservation site is reduced, which is often preferred when designating conservation areas. The Pan-European strategy is based on national *in situ* conservation. In the future, a situation can emerge, where the national gene pools need to be supplemented from other countries. This is not necessarily met by the current conservation effort, where e.g. extinction of gene pools at the edges of the present distribution range, may eliminate the genetic variability needed in areas forming the future edges of the distribution range.

Future shifts in species distribution with climate change thus may need even stronger conservation efforts, to assure the genetic diversity for the future. In this context, decisions made about conservation in one country have potential implications for neighbouring countries as well. A steppingstone to prevent such loss of genetic variation could be the transfer of gene pools by assisted gene flow. Transfer of gene pools is well known from provenance research and breeding. A new Danish research and pre-breeding programme, attempting to cope with adaptation to climate change, includes transfer of gene pools from southern parts of Europe, not previously seen as suitable for the Danish climate. This is also the case for Norway and Finland with transfer of Norway spruce, for example, provenances with late growth start are recommended for use in regions with high risk of spring frost. In Sweden, the use of seed material with a longer transfer from other regions has been an active way to improve the regeneration forestry during the latest generation particularly in southern Sweden. One may of course discuss whether gene flow from transferred gene pools into *in situ* conservation areas is wanted or not.

3.2.3. Climatic zones

For work at national level and for the Nordic region the question is whether the EUFORGEN climatic zones after de Vries *et al* (2015) reflects the differences in climate and the differences in adaptive diversity in our forest trees. We know that several of our forest tree species show strong clines in e.g. phenological traits following climate gradients, climate gradients at the Nordic level are not reflected in the current climatic zoning used by EUFORGEN. The zoning however may be feasible for reporting in a European context.

Nordic countries are therefore still advised to work further on more detailed climatic zoning and conservation efforts nationally. Some Nordic countries have already developed their own more detailed climatic zoning for their country, to get a more holistic proxy of genetic diversity.

3.2.4. Pests and diseases

Emergence of new pests or diseases are threats to any conservation programme. The latest major example is the ash dieback occurring in Europe. The dieback spread rapidly, and the level of natural resistance is low. In Denmark high levels of resistance is only present in 1-5 % of the trees. In such a case, rebuilding of a breeding population cannot rely on the trees surviving in designated gene conservation areas, but collections had to be carried out throughout the country (Kjær et al. 2017). In Finland the only gene reserve forest of ash has been severely damaged by ash dieback although not completely vanished. Other Nordic countries experience the same. Attempts have been made to develop a cryopreservation method but so far this not been successful enough to be taken into practical level. In any case cryopreservation is only a supporting emergency method which will not solve the problem of insufficient resistance. To support long-term conservation of ash in the Nordic-Baltic region, a network has been established under the SNS-Efinord funds. The project's general aim is to continue the efforts started in the partnering Nordic and Baltic countries leading to restoration of ash trees in the region and to develop and establish a set of 2nd generation genetic test trials that can be crucial for ash conservation.

Another genus with severe disease threat in Finland is elms. The Dutch elm disease has not reached Finland yet because the carrying insect cannot survive the low winter temperatures, but this situation is expected to change with climate change. As a precautionary measure a cryopreservation project has been initiated for both wych elm (*Ulmus glabra*) and white elm (*Ulmus laevis*).

Diversity of genetic resources and availability of healthy planting material of trees is an essential prerequisite for sustainable production of renewable forest biomass for the needs of bioeconomy. Alien pests and pathogens are increasingly spreading with planting materials, often because they escape inspections. In the new environment, and even more so with climate change, some of these alien organisms may develop an invasive character, posing a severe threat to the stability of our forests and the biodiversity associated with them.

The spread of pests and diseases is an internationally important problem. Invasions of organisms that have become pests have been noted increasingly in the literature (Liebhold *et al.*, 2017) and the trend appears to be continuing despite international phytosanitary rules to minimise the risks of pest movements between countries and ecosystems.

With regard to the threats of pests and diseases, it could be interesting to look more at conservation across borders. Would it be possible to conserve forest genetic resources for instance *ex situ* in Iceland, as a precautionary measure with regard to the threat of climate change or pests and diseases, which have not spread to Iceland?

3.2.5. Conservation and breeding

Genetic improvement of the trees in our Nordic forests has a relatively short history compared to agricultural crops. Even for major forestry trees, the breeding populations generally have broad genetic variation, with great opportunities for genetic progress through selection. This situation is also suitable for managing the gene pool for conservation purposes, and gives means to study the heritable nature and population genetics of the specific tree species (Pâques, 2013). One example is Skogforsk´s effort to manage the breeding programmes for Norway spruce and Scots pine, to achieve goals both for gene conservation and genetic gain production (Rosvall, 2011). To conserve valuable breeding material, clonal archives separated from seed orchards is often used. In addition, for the less commercial deciduous tree species, an active management model has been proposed, which is less resource intensive than Skogforsk's traditional tree breeding (Rosvall and Stener, 2013).

Especially for species with less intensive breeding programmes, GCU units may serve several purposes. They can be used as a source for adding new material to breeding programmes, and single trees can be identified and used as study objects in genetic research. Seeds from GCU units can be used in genetic trials as reference material.

4. Conclusions and recommendations for future work

1. Conservation efforts to secure forest genetic resources, based on the FAO Global Plan of Action and the EUFORGEN Pan-European conservation strategy, is being implemented across the Nordic region. There is a need to further develop the European work at Nordic and national level, including establishment of conservation units for more species, and development of more specific climatic zoning to assess the genetic diversity conserved.

2. There is a question whether traditional *in situ* conservation efforts as stated in the Pan-European strategy are enough to secure the genetic resources against future challenges, including climate change and pests and diseases. Cryopreservation and assisted migration have been mentioned as additional measures for particular genetic resources at stake. The question on how to proceed and make the work as resilient as possible for the future, needs to be discussed at a Nordic and European level.

3. Work on conservation of forest genetic resources in the Nordic region is a national responsibility, supported by European and Nordic cooperation. Through strategies, plans and management efforts, each country will continue their efforts, to secure a long-term conservation of forest genetic resources. Continued cooperation between the Nordic countries through NordGen, is important to sustain the work and secure the conservation of species on a regional level.

4. Hitherto there has been no systematic evaluation of how the GCU units established under the European programme cover the species genetic diversity. Evaluation, identification of conservation gaps, as well as characterisation of genetic variation captured by the GCU units, could be further developed in cooperation on a Nordic level.

5. There is need for continued development of knowledge and methods in accordance with the changing challenges. The NordGen Forest Working Group on Genetic Resources initiates activities and discussions that can improve or guide the conservation and use of genetic resources of forest trees in the Nordic region. In addition, the annual thematic days and conferences, initiated by the NordGen cooperation, give opportunities for discussions and exchange of information for conservation and use and to contribute to the establishment of the best possible Nordic forests for the future.

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6. Attachment - status

Status in the Nordic region per September 2019. Number of conservation units per species, aggregated climatic zone (based on Metzger *et al*) and country.

Species/ Climate zones	Extremely cold (ABCDF)	Cold and moist (EG)	Cool and dry (HI)	Cool and moist (J)
Acer campestre		Denmark - 4	Denmark - 1	
Acer platanoides		Denmark - 5 Finland - 4 Norway - 2 Sweden - 3		Denmark - 1
Alnus glutinosa		Denmark - 15 Sweden - 24	Sweden - 1	
Alnus incana		Sweden - 10		
Betula pendula	Finland - 1 Sweden - 1	Denmark - 11 Finland - 4 Sweden - 7		Denmark - 1
Betula pubescens	Finland - 2 Iceland - 1 Sweden - 1	Denmark - 11 Finland - 6 Sweden - 22		
Carpinus betulus		Denmark - 10 Sweden - 11		
Corylus avellana		Sweden - 9		

Fagus sylvatica		Denmark - 13 Norway - 2 Sweden - 37	Sweden - 3	
Frangula alnus		Denmark - 15		
Fraxinus excelsior		Denmark - 11 Finland - 5 Norway - 3 Sweden - 20		Denmark - 1
Ilex aquifolium		Norway - 3		
Juniperus communis		Sweden - 1		
Malus sylvestris		Denmark - 12	Denmark - 1	Denmark - 2
Picea abies	Finland - 3 Norway - 3 Sweden - 8	Finland - 8 Norway - 2 Sweden - 182		
Pinus mugo[1]				Denmark - 1
Pinus sylvestris	Finland - 5 Sweden - 8	Finland - 17 Sweden - 106	Sweden - 2	
Populus tremula		Denmark - 14 Sweden - 53		Denmark - 2
Prunus avium		Denmark - 13 Sweden - 5		Denmark - 2
Prunus cerasifera[1]		Denmark - 2		
Prunus padus		Denmark - 7 Sweden - 2		
Quercus petraea		Denmark - 9 Norway - 2 Sweden - 12		
Quercus robur		Denmark - 14 Finland - 2 Norway - 3 Sweden - 39	Sweden - 4	

Salix caprea	Sweden - 1	Sweden - 7	Sweden - 1	
Sorbus aucuparia	Sweden - 1	Denmark - 25 Sweden - 1		
Sorbus intermedia		Denmark - 3		
Sorbus torminalis		Denmark - 1		
Taxus baccata		Norway - 3		
Tilia cordata		Denmark - 5 Finland - 5 Norway - 3 Sweden - 15	Sweden - 1	
Tilia platyphyllos		Denmark - 1		
Ulmus glabra	Norway - 1	Denmark - 7 Finland - 1 Norway - 3 Sweden - 9		Denmark - 1
Ulmus laevis		Finland - 2		

[1] Non-native tree species in the Nordic countries.