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Complementary report

State of forest genetic resources in Norway 2020

to the FAO 2nd report on State of the World´s Forest Genetic Resources

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“State of forest genetic resources in Norway 2020” er det norske bidraget til den neste FAO-rapporten «State of the World´s Forest Genetic Resources» (forventet 2023). Den norske rapporten ble levert til FAO i juni 2020 og presenterer status for bevaring, bærekraftig bruk og utvikling av skogtregenetiske ressurser i Norge, og gir utfyllende informasjon til «2nd Country Progress Report for Norway» (vedlegg I).

“State of forest genetic resources in Norway 2020” is the Norwegian delivery to the next FAO report on “State of the World´s Forest Genetic Resources” (expected 2023). The Norwegian report was delivered to the FAO in June 2020 and presents the current status of conservation, sustainable use and development of forest genetic resources in Norway, complementing the “2nd Country Progress Report for Norway” (Annex I).

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Kjersti Bakkebø Fjellstad & Tore Skrøppa

Abbreviations and Acronyms

CBD Convention on Biological Diversity

EUFGIS European Information System on Forest Genetic Resources

EUFORGEN European Forest Genetic Resources Programme

FAO The Food and Agriculture Organization of the United Nations

FGR Forest genetic resources

FRA FAO Global Forest Resources Assessment

FOREST EUROPE Ministerial Conference on the Protection of Forests in Europe

GCU Genetic conservation unit

NFI National Forest Inventory

NIBIO Norwegian Institute of Bioeconomy Research

NMBU Norwegian University of Life Sciences

NordGen Nordic Genetic Resource Center

OECD Organisation for Economic Co-operation and Development

PEFC Programme for the Endorsement of Forest Certification schemes

SGSV Svalbard Global Seed Vault

SSB Statistics Norway

Contents

Sammendrag

Skog er viktig i Norge. Det er uttalt politisk vilje til å styrke skogens bidrag for økonomisk verdiskaping i landbruket og for å nå viktige mål knyttet til energi, klima, miljøverdier og økosystemtjenester. Skogressursene er viktige for å opprettholde et bærekraftig landbruk og matproduksjon over hele landet, ettersom inntekt fra skogen bidrar til den totale inntekten for mange aktive bønder. Skogene er også viktige for rekreasjon og for folkehelsa.

Skogtregenetiske ressurser i Norge brukes i produksjonsskogbruk, til skogplanting etter hogst og på annet areal, eller til treslagsskifte. De brukes også til juletreproduksjon, til landskapsformål eller i parker og hager.

De norske skogene kan grovt deles inn i tre hovedtyper; boreal skog, lauvskog og blandingsskog. Skogene består i stor grad av våre to bartrær, gran (*Picea abies*) og furu (*Pinus sylvestris*), og de to bjørkeartene hengebjørk (*Betula pendula*) og bjørk (*B.pubescens*). De to bartrærne er de økonomisk viktigste treslagene og de eneste som aktivt forvaltes for skogproduksjon i det kommersielle skogbruket. Til sammen dekker de 48 % av skogarealet og utgjør 88 % av den årlige hogsten.

Treslagssammensetningen og utbredelsen av skogtrær i Norge bestemmes i stor grad av innvandringen etter siste istid, påfølgende klimatiske endringer og menneskelig aktivitet. Nyere studier basert på DNA-funn, har blant annet gitt støtte til hypotesen om at gran og furu overlevde i isfri områder i Skandinavia under den siste istiden.

Alle naturlig forekommende skogtrær i Norge er vurdert med hensyn til sårbarhet. Seksten arter er vurdert som *utsatt* på grunn av marginal utbredelse, insektpollinering, begrenset seksuell reproduksjon, sykdommer eller endemisme. Dette omfatter ni asalarter, i tillegg til ask, søtkirsebær, villeple, barlind, kristtorn, alm og lind. To asalarter, nordlandsasal og smalasal, er vurdert som *truet*.

Kunnskap om status for skogtrærnes genetiske variasjon, utvikling og tilpasning er viktig for god forvaltning av skogtregenetiske ressurser. Vi har kunnskap om genetisk variasjon på ett eller flere nivåer for 18 av de naturlig hjemmehørende treslagene. Dette er basert på studier av morfologi, adaptive produksjonsegenskaper eller gjennom molekylær karakterisering, eventuelt en kombinasjon av disse. Det er likevel kun gran vi har gjennomgående god kunnskap om, og det er flere treslag vi mangler informasjon om.

Basert på det europeiske samarbeidet for bevaring av skogtregenetiske ressurser, EUFGIS, er 31 *in situ* bevaringsenheter etablert i 24 forskjellige naturvernområder i Norge. Totalt omfatter dette elleve treslag. Siden 2018 er det også etablert dynamiske *ex situ* bevaringsbestand for gran i åtte plantede bestand på Østlandet.

Skogplanteforedling i gran startet i Norge for mer enn 70 år siden, med utvalg av plusstrær i naturlige populasjoner og påfølgende podede frøplantasjer på 1960- og 1970-tallet. Norge er delt inn i åtte foredlingssoner for optimal bruk av foredlet materiale. I hver sone er foredlingspopulasjonen delt inn i en eller flere underpopulasjoner, som hver inneholder 50 individer som ikke er i slekt, for å sikre genetisk variasjon.

Rapporten “State of forest genetic resources in Norway 2020” er det norske bidraget til den neste FAO-rapporten «State of the World´s Forest Genetic Resources» (forventet ferdig i 2023). Den norske rapporten ble levert til FAO i juni 2020 og presenterer status for bevaring, bærekraftig bruk og utvikling av skogtregenetiske ressurser i Norge. Rapporten gir utfyllende informasjon til 2nd Country Progress Report for Norway (vedlegg I).

Noen anbefalinger fra rapporten:

Bevaring:

- Sikre bevaring av flere treslag og øke etableringen av *in situ* bevaringsområder for skogtregenetiske ressurser
- Styrke samarbeidet med miljømyndighetene og andre partnere
- Det bør utvikles strategier for *ex situ* bevaring av marginale treslag, samt for genetiske ressurser for treslag truet av sykdom

Kunnskap og forvaltning:

- Sikre kunnskapsbasert forvaltning av skogtregenetiske ressurser, gjennom blant annet å styrke dokumentasjon og karakterisering
- Styrke et nasjonalt informasjonssystem for georefererte data om opprinnelse, bevegelse og bruk av skoglig formeringsmateriale
- Eksisterende plantehelseregler bør kontinuerlig oppdateres med forskningsbasert kunnskap
- Utvikling av formeringsmaterialer av skogtrær for planting i grøntanlegg og parker

Internasjonalt samarbeid:

- Bidra til å styrke internasjonalt samarbeid innen skogtregenetiske ressurser, ved fortsatt deltakelse i nordisk og europeisk samarbeid innen forskning, bevaring og bruk, i tråd med eksisterende arbeid i NordGen og EUFORGEN

Executive summary

Forests are of great importance for the Norwegian society. It is an expressed political aim to strengthen the contribution from forests to the economic value creation in agriculture and to reach important goals related to energy, climate, environmental values and ecosystem services. The forest resources are important for maintaining a sustainable agriculture and food production across the country, as income from harvesting forest contributes to the total revenue for many active farmers. The forests are further important for recreational activities and thus for public health.

Forest genetic resources in Norway are used in production forestry, when forests are regenerated after harvest, in afforestation on treeless land or for the replacement of other tree species. They are also used for Christmas tree production, for landscaping purposes or for ornamental use in parks and gardens.

The Norwegian forests can broadly be classified into three major types: coniferous evergreen boreal forest, broadleaved forest and mixed forest. The forests are to a large extent formed by two conifers, *Picea abies* (Norway spruce), and *Pinus sylvestris* (Scots pine), and the two birch species *Betula pendula* and *B. pubescens*. The two conifers are economically the most important species and are the only species actively managed for wood production in the commercial forestry; together they cover 48 % of the forest area and 88 % of the annual forest fellings.

Species composition and distribution of forest trees in Norway are largely determined by the immigration of tree species after the last Ice Age, subsequent climatic changes and human activities. Recent studies, based on ancient DNA evidence, have given support to the hypothesis that the two conifers *Picea abies* and *Pinus sylvestris* survived in ice-free refugia of Scandinavia during the last glaciation.

Native forest tree species have been characterised due to their endangerment. Sixteen species were considered exposed (9 *Sorbus spp., Fraxinus excelsior, Malus sylvestris, Prunus avium, Tilia cordata, Taxus baccata, Ilex aquifolium, Ulmus glabra*) owing to marginal occurrences, a great proportion of insect-pollination, limited sexual reproduction, diseases and endemism. Two *Sorbus spp.* are considered threatened.

For five native tree species genetic variability for morphological, adaptive and production traits have been studied at the provenance level and for six species such studies have been made both for provenances, populations and families within populations. *Picea abies* is the only species that has a sufficient characterisation of genetic diversity at the provenance, family and individual level.

Based on the European cooperation on gene conservation, EUFGIS, 31 *in situ* gene conservation units are established in 24 different nature protection areas, comprising eleven forest trees species. Since 2018, dynamic *ex situ* conservation stands for forest genetic resources have been established in 8 planted Norway spruce stands in Eastern Norway.

Tree breeding activities in *Picea abies* started in Norway more than 70 years ago with the selection of plus trees in natural stands, and grafted seed orchards were established in the 1960s and 1970s. Norway is divided into eight breeding zones, for optimal use of adapted reproductive materials. In each zone the breeding population is divided into one or more sub-populations, each containing 50 unrelated individuals to ensure genetic diversity.

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Recommendations include:

- aiming conservation at more species and step up the establishment of *in situ* gene conservation units for forest genetic resources, including strengthened cooperation with the environmental authorities and other partners. Strategies for *ex situ* conservation of marginal species and genetic resources of species threatened by diseases should be developed
- assuring knowledge-based management of all forest genetic resources. Thus, documentation and characterisation should be strengthened. Work should be undertaken to strengthen a national information system for geo-referenced records of the origin, movement and use of forest reproductive material at stand level. Existing phytosanitary regulations should be continuously updated with science-based knowledge. Development of reproductive materials of woody plant species for planting in the landscape, parks, should be given weight
- continued participation in Nordic and European cooperation in research, conservation and use, in line with existing work in NordGen and EUFORGEN

1 Value and importance of forest genetic resources

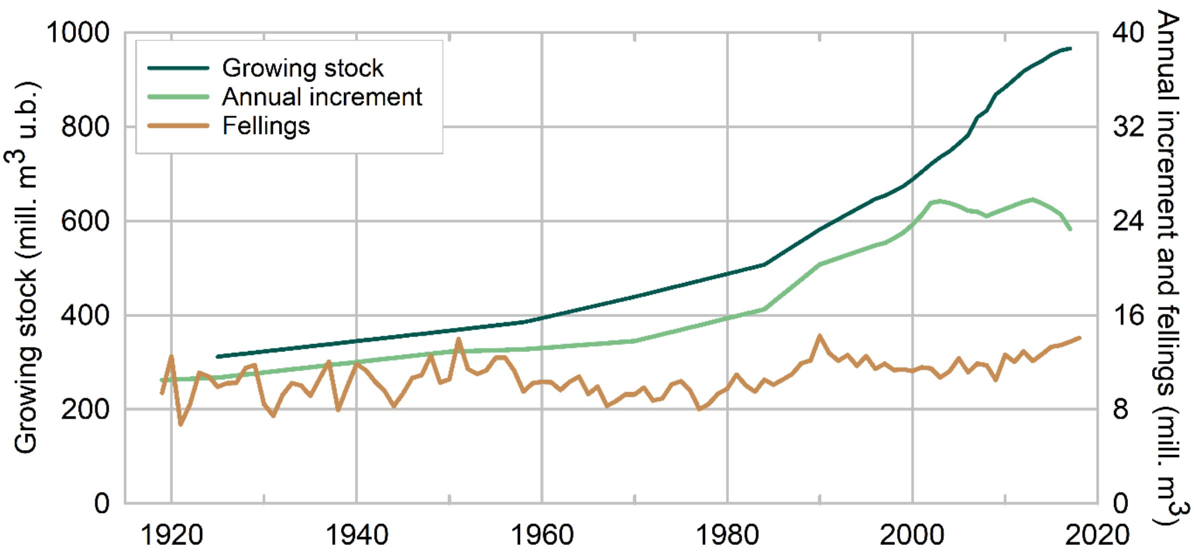
1.1 The role of forests and the forest sector

Forests are of great importance for the Norwegian society. They provide a whole range of services that contribute to the living environment and social welfare, as well as economic development. The forest resources are of great historical importance and have played a major role in developing trade and industry.

In the period 2015-2019 with midyear 2017, the total growing stock in Norwegian forests was 1133 million m^3 over bark for trees with a diameter at breast height equal to or larger than 5 cm, with an annual increment of about 24 million m^3. Over the last 100 years the total forest fellings has been between 7 and 14 million m^3. This is considerably lower than the annual increment, as shown in Figure 1.

At the beginning of the 20th century the forests in Norway were sparsely stocked, with low volumes of wood per hectare. Export of lumber/timber, fire-setting in mines, and firewood and building materials for a growing population had required large quantities of wood. The expansion of pulp and paper industries opened up a market for smaller dimensions. Officials at this time were worried excessive tree felling would impede necessary regeneration of future forests.

An improved legal framework, targeted forest policy, education of advisers and forest land owners, transition from selection cutting to clear-cut logging, planting and afforestation are among the most important factors leading to a change in the forests. During the last 100 years the forests have grown larger, denser and with larger trees. With the existing level of fellings and forest management, the annual increment has more than doubled and the growing stock has more than tripled the level documented by the first National Forest Inventory in 1932. The amount of dead wood, old forest and deciduous trees, which is important for biological diversity, has increased considerably during the same period.



Source: Norwegian Institute of Bioeconomi Research and Statistics Norway

Figure 1. Growing stock (under bark), annual increment and fellings in Norwegian forests 1919-2017.

1.2 Economic, environmental, social and cultural values

Norwegian forestry and the wood industry continue to have big financial importance today, at a national, regional and local level. The aggregated gross product of roundwood sold to the manufacturing industry in 2019 amounted to 4.8 billion NOK (≈ € 480 millon). The same year forestry, wood and paper products had a gross product of approximately 55 billion NOK (≈ € 5.5 billion). Approximately 55 % of the wood of the two conifers harvested is sold to the timber and wood industry and 45 % to the pulp and paper industry. Biomass and timber from Norwegian forests will continue to play an important role in the years to come, as renewable resources that can help us meet the challenges of climate change.

Forestry in Norway is characterized by small-scale properties, combining forestry and agriculture. This structure is based on the Norwegian topography, varying production conditions and the ownership structure of Norwegian forests. In 2018, Norway had 125 566 forest owners with more than 2.5 hectares of forest (productive and non-productive forest land). Of these properties, 96 % are privately owned, and constitute 73 % of the total forest area. The average size of privately owned farms with forest resources is 73 hectares. Figure 2 shows the percentage distribution of forest ownership by area.

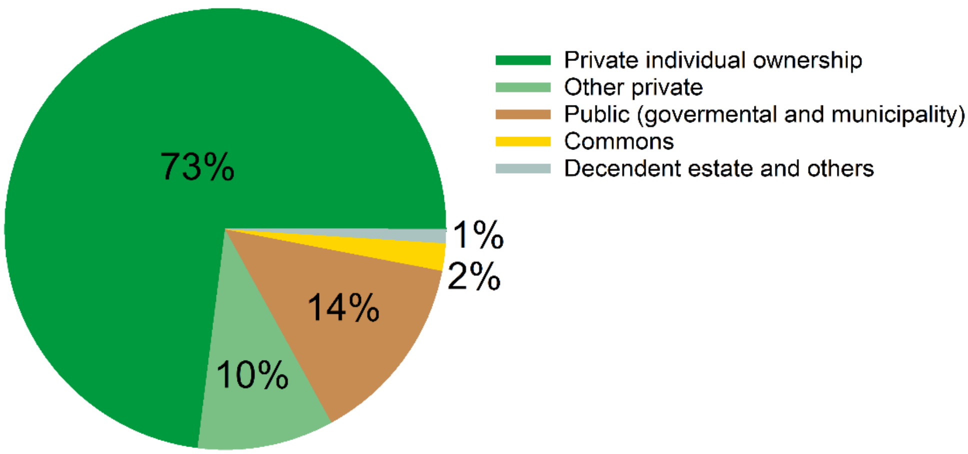


Figure 2. Forest ownership. The percentage distribution of forest ownership by forest area. Source: SSB

It is an expressed political aim to strengthen the contribution from forests to the economic value creation in agriculture and to reach important goals related to energy, climate and environmental values. The forest resources are important for maintaining a sustainable agriculture and food production across the country, as income from harvesting forest contributes to the total revenue for many active farmers. The forests are further important for recreational activities and thus for public health.

Norwegian forest policy, as well as the environmental standards that forest owners are committed to follow, emphasise environmental considerations, such as maintaining and developing biological diversity, and the social and cultural functions of forests. The share of virgin forests is small in Norway. There are strong concerns that Norwegian forestry is environmentally sustainable and takes sufficient consideration of biological diversity and threatened habitats. Biodiversity rich habitats are registered and mapped in forest management plans. This registration is being done according to a standardized and well documented system.

Important areas for biological diversity are being inventoried on the basis of knowledge about species and their habitat requirements.

Protective forests are regulated in the Forestry Act. The main function of a protective forest is to protect climatically vulnerable forests and other forests against damages and constitutes mainly the forest bordering mountain areas.

The right of public access to outlying land, including forests, is an old and important principle in Norway. The general public may use the forests for recreational activities and sports at any time of year. The principle of public access is underlined by the forest policy and the environmental standards used by forest owners. Traditional activities such as skiing, hunting, fishing, berry picking and mushrooming are still important, while modern activities such as off-road biking are increasingly popular. Norwegian forests are often mentioned as important for public health and as an educational arena for children and youth. Using the forests for recreation and sports is considered to have a positive impact on both physical and mental health.

Figure 3. Cross country skiing is a popular recreation activity in the Norwegian forests.

Photo: Arne Steffenrem/NIBIO

Forest genetic resources are considered important both as one element of the biological diversity that should be conserved for future generations and as the basis for the supply of forest reproductive material for the regeneration of forest after harvest.

Growing forests capture CO^2, and active management including the choice of proper reproductive material do play an increasing part in reducing CO^2 emission. In 2018 living tree biomass sequestrated 27,8 million tons (Mt) CO^2, which was 53 % of the national CO^2 emissions. An important goal for both the Government and the wood processing industry is further to increase the use of wood wherever it can replace materials with more negative environmental impact.

1.3 Contributions towards Sustainable Development Goals

Forest genetic resources contribute to several sustainable development goals[1]. These include goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all, goal 12: Ensure sustainable consumption and production patterns, goal 13: Take urgent action to combat climate change and its impacts and goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Forests have a significant role in reducing the risk of natural disasters, including floods, droughts, landslides and other extreme events. At global level, forests mitigate climate change through carbon sequestration, contribute to the balance of oxygen, carbon dioxide and humidity in the air and protect watersheds, which supply 75% of freshwater worldwide.

Norwegian ecosystems are in a relatively good condition. Nevertheless, we also face challenges, and to maintain good condition in ecosystems good management must be continued. The white paper "Natur for livet", a Norwegian plan of action for biodiversity, describes Norwegian policy to protect, restore and promote sustainable use of ecosystems.

Forest genetic resources form the basis of sustainable forests and sustainable forest management, thus the conservation and sustainable use of forest genetic resources is an important contribution to sustainable development. In Norway, forest genetic resources play an important role not only in forestry, but also in carbon sequestration and other ecosystem services.

Since 2014 an annual report on sustainable forestry has been published by NIBIO on behalf of the Ministry of Agriculture and Food[2]. The report presents information and new knowledge related to forest resources, their use and development and contribution to sustainable development. The report includes a chapter on forest genetic resources.

Public awareness of the values related to forest genetic resources has increased in Norway during the last years. However, it will continuously be necessary to educate managers of forests and natural resources about the importance of forest genetic resources, and how to choose proper materials under changing climate conditions. A challenge is to promote awareness that long term considerations are necessary for the management of forest genetic resources.

1.4 Increased awareness on forest genetic resources

There is a general need to increase awareness on the value and importance of forest genetic resources, as a basis for adaptation and evolution of trees, and the need to assure proper conservation and sustainable use of these resources. Forest genetic resources must be addressed more systematically and become properly integrated in future strategies for both biodiversity conservation and sustainable forest management.

[1] https://unstats.un.org/sdgs/report/2020/

[2] https://www.nibio.no/en/subjects/forest/sustainable-forestry-in-norway?locationfilter=true

2 State of forests

2.1 State of forests and trends in their management

Norway is Europe's northernmost country, ranging over some 1750 km between 58 °N and 71 °N. The country's total area is 323,787 km² (excluding the islands of Svalbard and Jan Mayen). Its population is 5.37 million, with a population density of 16 people per km².

The total area covered by forests and wooded land is 14.2 million hectares and constitutes 44 % of the land area in Norway. Of this, 8.5 million hectares are forest area available for wood supply (productive forests).

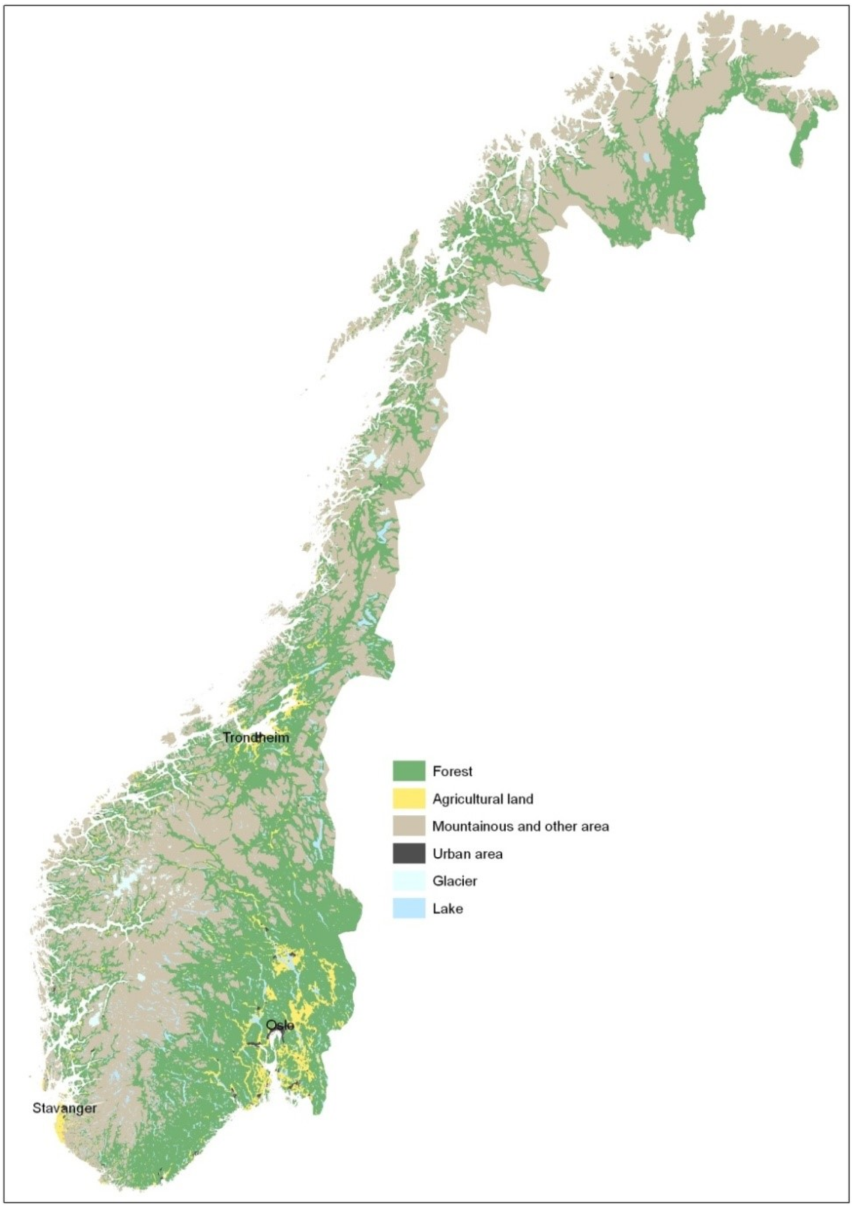


Figure 4. Map showing the forest area and other types of land in Norway. Source: NIBIO

Norway has substantial north-south and east-west climate gradients. Inland areas in northern and eastern Norway have a typical continental climate, with warm summers and cold winters. The entire coastline is characterised by a maritime climate, with relatively cool summers and mild winters.

Annual precipitation also varies. The zone with the highest annual rainfall lies about 30-40 km inland from the coast. The driest areas are the inland regions of Finnmark (in the far north), as well as parts of the valleys of eastern Norway. The length of the growing season, defined as the number of days with a mean temperature of more than 5 °C, varies between 200 days in south-western Norway and 100 days along the coast of eastern Finnmark. In the alpine regions, the growing season is even shorter.

The soil and topography of the Norwegian land area have, in addition to the climatic conditions, had a great impact on the extent of the forests, species composition and growth. The far largest portion of the forests is boreal coniferous forest with principal species Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), and with downy birch (*Betula pubescens*) and silver birch (*B. pendula*) as the dominating deciduous tree species. Boreal deciduous forests are an important component of the forests at high altitudes and in the northern areas. Hardwood forests which constitute only 1 % of the forest area, occur in the southern part of the country and in particular along the coast, while the coniferous forests dominate in the inland.

The current forest composition is greatly influenced by different human-forest interactions. During several centuries the forests have suffered from deforestation, and much of the present forests are the results of human-induced regeneration and various silvicultural treatments. The species composition and structure of the present forests in all ecological zones is thus significantly different from primeval forests.

Figure 5. Forest landscape at the lake Buvatnet in Norway. Photo: John Yngvar Larsson/NIBIO

The Norwegian forests can broadly be classified into three major types: coniferous evergreen boreal forest, broadleaved forest and mixed forest (Table 1). In addition to the 12.1 mill hectares of forests, other wooded land amounts to 2.1 mill hectares. The forests are to a large extent formed by two conifers, *Picea abies* (Norway spruce), and *Pinus sylvestris* (Scots pine), and the two birch species *Betula pendula* and *B. pubescens*. The two conifers are economically the most important species and are the only species actively managed for wood production in the commercial forestry; together they cover 48 % of the forest area and 88 % of the annual forest fellings.

Table 1. Major forest type categories and main tree species.

Major Forest Types	Area covered (hectares)	Main species
Coniferous evergreen forest	5.8 mill	*Picea abies, Pinus sylvestris,*
Broadleaved forest	4.2 mill	*Betula pubescens, B. pendula*
Mixed forest	2.1 mill	*P. abies, P. sylvestris, B. sp.*

The National Forest Inventory (NFI) has been an important basis for the development of forest policy since the beginning of the 20th century. The current NFI is a representative continuous sample-based survey, which apart from the field-based assessment of forest resources also yields a classification of the Norwegian mainland with respect to land types and land use, including non-forest land. The permanent sample plots are visited every five years. In addition to stand volume, increment and tree species, a range of parameters are measured to provide information about e.g. site productivity, stand structure, forest health, forest operation conditions, and biological diversity. The Norwegian system is to a certain extend unique, in that the inventories have been ongoing for 100 years, with an holistic view to statistics on forests.

2.2 Drivers of change in the forest sector, including challenges and opportunities

A main objective of the Forestry Act of 2005 is to promote sustainable forest management to re-establish the forest within three or four years after harvest. In the last period this goal has been focused, with inspection of the planted areas, and subsidies are given when a high number of seedlings are planted per hectare. This is part of the government's climate policy to increase the use of forest resources to mitigate CO^2 emissions by a higher biomass production in the forest. Investments have been made in forest tree breeding with the aim of producing genetically superior reproductive materials. More efforts have been made in silviculture and forest management planning and to follow up environmental measures. Economic grants and The Forest Trust Fund, which is a legal instrument to reinvest parts of revenues from forestry, has contributed to increased silvicultural efforts and sustainable forest management.

Under the Forestry Act, every forest owner must have an overall view of the environmental values and pay attention to them when carrying out activities in the forest. This is also an important part of the Norwegian PEFC Forest standard.

Protection of forests and forest ecosystems has increased quite a lot during the last 10 years. Voluntary protection by the forest owners is now the main strategy. Provisions on forest and on prioritized species and selected habitats in forests are regulated by The Nature Diversity Act of 2009. There is a great potential in strengthened cooperation with the environmental authorities on conserving forest genetic resources as part of the general forest protection.

Figure 6. Old Norway spruce forest, Vardåsen, Ås, Norway,2009.

Photo: Dan Aamlid/NIBIO

A regulation under the Nature Diversity Act is regulating the use of alien species, including non-native forest trees. A permit is required from the local environmental authority before establishing plantations based on forest reproductive materials of non-native tree species.

3 State of other wooded lands

3.1 State of other wooded lands

The definition of *other wooded land* as stated in the FAO Global Forest Resources Assessment 2020 is: *Land not defined as "forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.*

This chapter gives a very brief overview of the state of other wooded land in Norway.

The area of other wood land in Norway has increased with 11 % since 1990, and the growing stock has increased with 77 %.

Table 2. Other wooded land in Norway, 1990-2019. Growing stock measured in m^3 over-bark (o.b.). Source: NIBIO

	1990	2015-2019	% change
Other wooded land (area 1000 ha)	1 868	2 068	+11
Growing stock million m^3 o.b	4.86	8.62	+77
Growing stock coniferous million m^3 o.b	2.27	3.93	+73
Growing stock broadleaved million m^3 o.b	2.59	4.69	+81

A warmer climate favours seed maturation and germination, and hence contributes to trees establishing in areas with former marginal growing conditions. This together with less livestock grazing in outlaying fields leading to trees climbing into higher elevations. Afforestation occurs on abounded agricultural land. Theoretically this means that eventually areas with other wooded land would be considered forest land but so far, the areas shifting are too small to be monitored. At the same time land is converted to settlements and infrastructure.

The growing stock in terms of volume on other wooded land is only 0.7 % of the standing volume on forest land. The other wooded land is dominated by broadleaved trees accounting for about 54 % of the growing stock including trees higher than 0 cm (Table 2). Looking at trees with a diameter at breast height (dbh =1.3 meter) equal to or larger than 5 cm, *Pinus sylvestris* and *Betula spp*. accounts for about 43 % and 38 % of growing stock, respectively (Table 3). *Picea abies* makes up about 15 % of the growing stock and introduced coniferous species only 1 %. The remaining 3 % consist of different broadleaved trees.

3.2 Challenges and opportunities for forest genetic resources

There is little knowledge about other wooded land. There could be a need for better monitoring of these areas for grazing or other economic utilization, as well as for nature conservation restoration purposes, forest genetic resources migration and climate change mitigation.

Some pioneer tree species and bushes may typically be favoured in these areas. In the southern parts of Norway some of the noble hard woods, e.g. beech (*Fagus sylvatica*) could have a successful gene flow in these areas.

Table 3. Composition of growing stock (1000 m^3 over bark) on other wooded land, consisting of trees with a dbh ≥ 5 cm. Source: NIBIO

Species Scientific name	Growing stock 1000 m^3 o.b	%
Pinus sylvestris	2 728	42.7
Betula pendula, B. pubescens	2 410	37.7
Picea abies L. Karst	991	15.5
Sorbus aucuparia	112	1.7
Introduced *Picea* and *Pinus spp.*	65	1.0
Salix spp.	35	0.5
Ulmus glabra, Acer pseudoplatanus, Fraxinus, Corylus avellana, Alnus glutinosa	32	0.5
Populus tremula, Alnus incana	19	0.3
Quercus spp.	4	0.1
Total	6 396	100

4 State of diversity between tree species

4.1 Colonisation of tree species after the Ice Age

Species composition and distribution of forest trees in Norway are largely determined by the following factors: the immigration of tree species after the last Ice Age, subsequent climatic changes and human activities. The first tree species to establish after the ice retreated more than 10 000 years ago were birch (*Betula pubescens*), poplar (*Populus tremula*) and Scots pine (*Pinus sylvestris*). These species spread fast and to altitudes 200-300 m higher than the present timber line.

During the warm and dry period that later followed high temperature demanding species such as lime (*Tilia cordata*), common ash (*Fraxinus exelsior*) and oak (*Querqus robur, Q. petrea*) spread and formed forests in the southern and southwestern part of the country. Small remnants of these forests still exist. These and other deciduous tree species that occur as scattered trees in mixed stands with other species (e.g. *Fagus silvatica, Ulmus glabra, Acer platanoides, Prunus avium*) have their main distribution in warmer climates at more southern latitudes and occur in Norway today at the northernmost border of their natural range.

Figure 7. Most likely the northernmost population of *Fraxinus excelsior* in the world, lat. 63°40'.

Photo: Arne Steffenrem/NIBIO.

It was not until approximately 2,500 years ago, during a cooler and more humid period, that the conifer *Picea abies* started to form forest in Norwegian landscape (Figure 8). Norway spruce in Fennoscandia has its origin in the Russian plains, from where it migrated westwards, starting in the early Holocene. During a period of 7,000 years the species spread through Finland and northern Sweden, and from the Baltic region across the Baltic Sea through southern Sweden to southern Norway. The immigration of the south-eastern lowland area started 3,000 years ago, but the migration up the valleys to the species' present altitudinal boundary was not completed until the period 1,000-1,500 AD. The coastal spruce forest in Central Norway established rather late (approx. 1,300 AD). The present natural occurrence of Norway spruce is in south-eastern Norway from the sea level and up to 1000 m, and in Central and North Norway, north to lat. 67°N, at decreasing altitudes in the north. Outside this area the species has in the last century been planted both in western Norway and north of its natural boundary in northern Norway. In both regions it has become an important timber species.

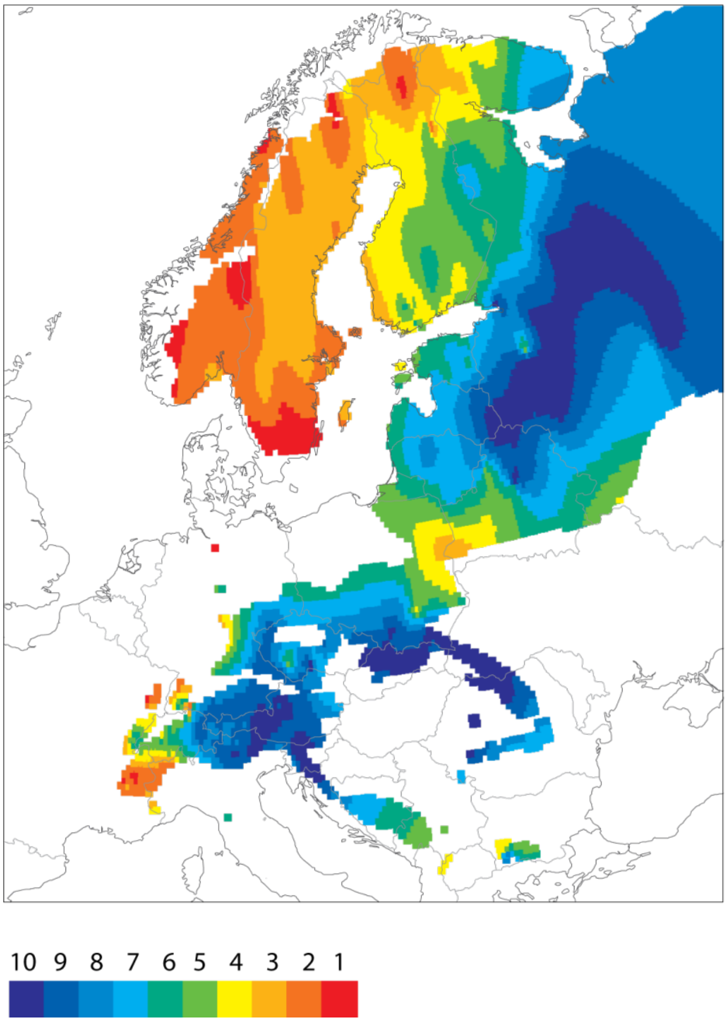


Figure 8. Map of fossil pollen for the inference of Holocene expansion in *Picea abies*. The map shows interpolated age (in time intervals of 1000 years before present) of *Picea abies* fossil pollen (threshold >= 2%). Map developed by Christoph Sperisen.

Recent studies, based on ancient DNA evidence from lake sediments and pollen, along with modern DNA samples, have given support to the hypothesis that the two conifers *Picea abies* and *Pinus sylvestris* survived in ice-free refugia of Scandinavia during the last glaciation. In Central Norway, *Picea abies* was present already 10 300 year ago, and on the coast of north-western Norway as early as 22,000 and 17,000 years ago, for pine and spruce, respectively.

4.2 Characterisation of genetic resources

In 2001 a description of life history traits, such as geographic range, occurrence, pollination vector and seed dispersal of native Norwegian forest tree species was made. Table 4 includes a revised version of this.

Table 4. Native forest tree and woody plant species in Norway and their characteristics

Species Scientific name	Geographic range	Occurrence	Pollination vector	Seed dispersal	Northern limit in Norway?	Genetic resource category
Picea abies	widespread	stand	Wind	wind		vital
Pinus sylvestris	widespread	stand	Wind	wind	yes	vital
Juniperus communis	widespread	scattered	Wind	birds	yes	vital
Taxus baccata	Limited	scattered	Wind	birds	yes	exposed
Populus tremula	widespread	stand/scattered	Wind	wind		vital
Betula pendula	widespread	stand/scattered	Wind	wind		vital
Betula pubescens	widespread	stand/scattered	Wind	wind		vital
Alnus incana	widespread	stand/scattered	Wind	water/wind		vital
Alnus glutinosa	Medium	stand/scattered	Wind	water/wind		vital
Coryllus avellana	Medium	stand/scattered	Wind	mammals	yes	vital
Prunus padus	widespread	scattered	Insect	birds	yes	vital
Fagus sylvatica	Marginal	stand/scattered	Wind	birds	yes	uncertain
Quercus robur	Limited	stand/scattered	Wind	mammals/birds	yes	uncertain
Quercus petraea	Limited	stand/scattered	Wind	mammals/birds	yes	uncertain
Acer platanoides	Limited	scattered	Insect	wind	yes	uncertain
Fraxinus excelsior	Limited	stand/scattered	Wind	wind	yes	exposed
Ilex aquifolium	Limited	scattered	Wind	birds	yes	exposed
Malus sylvestris	Limited	scattered	Insect	mammals/birds	yes	exposed
Prunus avium	Marginal	scattered	Insect	birds	yes	exposed
Tilia cordata	Limited	stand/scattered	Insect	Wind	yes	exposed
Ulmus glabra	Medium	stand/scattered	Wind	Wind	yes	exposed
Rhamnus cathartica	Marginal	scattered	Insect	birds		exposed
Frangula alnus (Rhamnus frangula)	widespread	scattered	Insect	birds		vital
Salix caprea	widespread	scattered	Insect	Wind	yes	vital
Salix pentandra	widespread	scattered	insect	Wind		vital
Salix myrsinifolia	widespread	scattered	insect	Wind		vital
Salix cinerea	Medium	scattered	insect	wind		vital
Salix triandra	Marginal	scattered	insect	wind		exposed
Sorbus aucuparia	widespread	scattered	insect	birds		vital
Sorbus hybrida	Limited	scattered	insect	birds	yes	exposed

Sorbus meinichii [1)]	Marginal	scattered	insect	birds	yes	exposed
Sorbus subsimilis[1)]	Marginal	scattered	insect	birds	yes	exposed
Sorbus subpinnata[1)]	Marginal	scattered	insect	birds	yes	exposed
Sorbus subarranensis[1)]	Marginal	scattered	insect	birds	yes	exposed
Sorbus negléctа[1)]	Marginal	scattered	insect	birds	yes	threatened
Sorbus lancifólia[1)]	Marginal	scattered	insect	birds	yes	threatened
Sorbus norvegica[1)]	Marginal	scattered	insect	birds	yes	exposed
Sorbus rupicola	Limited	scattered	Insect	birds	yes	exposed
Sorbus intermedia	Marginal	scattered	Insect	birds	yes	exposed
Sorbus aria	Marginal	scattered	Insect	birds	yes	exposed

[1] Species that are considered endemic in Norway.

Based on a revision of work from 2001, and genetic knowledge of the species, their genetic resources have been characterised as vital, uncertain, exposed or threatened (Table 4). Special for Norway is that 25 of the native tree species have their northern limit in this country. Of the 12 native Sorbus species, seven are endemic. Eight of these species are included in the Norwegian Red List for Species 2015 as either exposed or threatened.

Twelve widely distributed species with effective dispersal of pollen and seeds were considered vital (e.g. *Betula spp., Alnus incana, Pinus sylvestris, Picea abies*). Four species were considered uncertain (*Quercus spp., Acer platanoides, Fagus sylvatica*) because of limited ranges, scattered occurrences and possibly less effective dispersal of seeds and/ or pollen than the former group. Sixteen species were considered exposed (9 *Sorbus spp., Fraxinus excelsior, Malus sylvestris, Prunus avium, Tilia cordata, Taxus baccata, Ilex aquifolium, Ulmus glabra*) owing to marginal occurrences, a great proportion of insect-pollination (all except for *Taxus baccata* and *Ilex aquifolium*), limited sexual reproduction (*Tilia cordata*), and endemism (some *Sorbus* spp.). The population size of *Fraxinus excelsior* is being reduced due to attacks by the fungus *Hymenoscyphus fraxineus*, which kills trees at all ages. *Ulmus glabra* was classified as exposed because of the Dutch Elm disease that may reduce the genetic variability at the population level. Two *Sorbus spp.* are considered threatened.

Figure 9. One of the endemic *Sorbus species* in Norway, *Sorbus meinichii* (Lindeberg ex. C. Hartman) Hedlund. It has probably originated through one or several hybridization events between *Sorbus aucuparia L.* and *Sorbus hybrida L.*

Photo: Per Harald Salvesen/UiB

Introduced tree species planted in Norway is quite limited. Exotic conifer species have been tested since the beginning of the 20th century, but except for the planting of *Picea sitchensis* and the hybrid *P. lutzii* (*P. sitchensis* x *P. glauca*) along the coast of western and northern Norway, no exotic species are used to any large extent in the commercial forestry. Complaints are being made that natural regeneration of the two species is a threat to the native vegetation which may be suppressed. A permit is required from the local environmental authority before establishing plantations based on forest reproductive materials of non-native tree species.

4.3 Drivers of change and threats to species

As mentioned above, there are some tree species or genetic resources which are characterized as exposed or threatened (Table 4). Climate change and the increase of pests and diseases are among those changes which have an actual and/or potential continued negative effect.

4.3.1 Climate change

The report «*Klima i Norge 2100*» gives an overview of assumed development of the climate in Norway under different emissions scenarios. Climate change already has affected, and will continue to affect, growth and dynamics in Norwegian forests, both positively and negatively. The report shows for instance that the annual mean temperature has increased by approximately 1 ° C from 1900 to 2014. Annual rainfall for the country as a whole has increased by approximately 18 % since 1900. There has also been an increase in intensity and frequency of rainfalls.

Climate change primarily provides opportunities for increased forest production in Norway, given that proper forest management is conducted. But some climate induced damages to forests may be mentioned. Due to warmer winters, more frost damages are expected. Further, drought damages may increase in some areas of Norway, especially for *Picea abies* in the South-East of Norway. Storm and wind damages are also expected, predominantly in the autumn and during winter time. Several pests will be favoured by climate change.

4.3.2 Pests and diseases

Forest health is to a large extent affected by climate and weather conditions, either directly by e.g. drought, frost and wind, or indirectly when climatic conditions influence the occurrence and abundance of pests and diseases. Invasive damaging agents, both species which have already established and species which may migrate to Norway in the future, are potential challenges to the management of future forest resources.

Pests and biotic disease causing agents have a much shorter generation time than trees, which gives them a better opportunity to adapt faster to climate change than trees. Many pests spread quickly over long distances using both natural and human-assisted pathways (e.g., plant trade and timber transport), and a warmer climate allows more of these species to survive in our northern latitude. Establishment of new pests in tree populations without genetic resistance, may have major economic and ecological consequences.

Spruce bark beetles

Results from the Norwegian spruce bark beetle monitoring showed only a moderate increase in *Ips typographus* populations in 2018, despite the dry and warm summer, and in most Norwegian counties populations were well below the epidemic levels of the 1970s. However, there has been an increasing trend for the spruce bark beetle population in Mid-Norway during the past years. *Ips amitinus*, a close relative of *I. Typographus*, has spread rapidly through northern Europe recently. Model simulations including potential future climate parameters show that this species will find viable conditions in a warmer climate in northern Europe. *I. amitinus* has invaded Sweden and is monitored there.

Heterobasidion root rot

There are two species in the genus *Heterobasidion* which are causing severe disease in conifer forests in Norway. They differ from each other in relation to host trees and range. Root rot caused by *H. parviporum* mainly affects Norway spruce (*Picea abies*) and is common throughout the whole distribution area of spruce. Root rot on pine (*Pinus sylvestris*) is caused by *H. annosum sensu stricto* which also attacks spruce, common juniper (J*uniperus communis*), birch (*Betula spp*.) and other broadleaved species. Based on the spread biology of Heterobasidion root rot, one predicts that climate change will further increase the spread of the fungi in Norway.

Ash decline

Ash dieback caused by the fungus *Hymenoscyphus fraxineus* has since 2006 spread through most of the distribution range of *Fraxinus excelsior* (common ash) in Norway. In 2018, ash dieback was verified in Norway's northernmost ash forest. Results from our monitoring show that some trees have remained healthy, even after more than 10 years with ash dieback present. These trees and their seeds may be used in ash breeding programmes.

Phytophthora root rot

In 2018 and 2019, soil samples from imported, woody ornamental plants were analysed, and 19 Phytophthora species were found, although all plants had phytosanitary certificates. Several of the detected species are pathogens on forest trees such as common beech and grey alder. International trade with plants contributes to the spread of Phytophthora species. Although many Phytophthora species have already entered and established in Norway, it is important to limit further spread and infection pressure.

Disease on common aspen (Populus tremula)

Wilting of aspen has been observed during the last decade in Norway, especially in the northern parts and at higher altitudes in the south. The damage has increased and is now at an epidemic level, threating aspens with extinction in these areas. The cause of the disease has not yet been stated, but inoculation trials are currently ongoing.

5 State of diversity within tree species

5.1 State of genetic diversity

The first species and provenance trials with both native and introduced conifer tree species were planted in Norway approximately 100 years ago. Since then, short- and long-term field tests have provided knowledge about differences in genetic diversity in quantitative traits between species and of the within-species genetic variation among provenances, populations within provenances and within populations. Studies have particularly been made of traits that characterise adaptation to the climatic conditions in the northern environment, but also of variation in growth traits and wood and stem quality. More recently, molecular genetic studies have been initiated. In these studies, characterisation has been made of molecular diversity among and within populations, of colonization history, species hybridization and disease resistance. Attempts are also being made to identify genes or gene expressions controlling traits that are being selected for in the breeding of *Picea abies*. Table 5 presents native forest tree species and the type of material from which knowledge of genetic diversity is available. Molecular characterization has been done for nine species. For five species genetic variability in morphological, adaptive and production traits have been studied at the provenance level, and for seven species such studies have been made both for provenances, populations and families within populations. *Picea abies* is the only species that has a sufficient characterisation of genetic diversity at the provenance, family and individual level.

5.1.1 Genetic diversity in *Picea abies*

Recent molecular genetic studies confirm that the vast northern range of *Picea abies* was colonized from a large refugium during the last ice age on the plains of East-Europe and that the expansion westward and north took place along two main migration routes. The genetic structure of the species may also have been influenced by a smaller refugium along the west coast of Norway. Populations in southern Norway show relatively high levels of molecular genetic diversity compared to those of the most northern range of the species. In the north, limited seed and pollen production may have caused decreased diversity and increased inbreeding, reflecting the marginality of the species in the north.

The adaptation of Norway spruce to the climatic conditions have been characterized by traits measured in provenance, progeny and clonal trials. Measurements have been made of annual growth rhythm traits: the timing and duration of the annual growth period, frost hardiness development in the autumn and dehardening in the spring, and the occurrence of climatic damage under field conditions. All studies demonstrate a clinal variation in growth rhythm traits in natural populations from the south to the north and from low to high altitudes. The southern and lowland populations have the longest duration of the growth season, and consequently, have the highest growth potential. They also have the latest development of autumn frost hardiness. Responses to temperature and photoperiod are critical factors of the adaptive process of spruce populations and are genetically controlled. Within natural populations, a large genetic variation is present for adaptive traits that show clinal variation at the provenance level, also for growth and wood and stem quality traits. Such variability is also present in populations at the geographic margin of the species. Several studies have shown that seedlings of *Picea abies* can adjust the performance in adaptive traits by a rapid and likely epigenetic mechanism, through a kind of a long-term memory of temperature sum and photoperiod during seed production. These effects may have important implications for both gene conservation and for practical forest tree breeding.

5.1.2 Genetic diversity in other species

The studies demonstrate genetic variation among provenances both in annual growth rhythm and growth traits for most species. This variation is often clinal and related to latitude, and the southern provenances generally have the best growth. Populations from the same latitude may perform differently for the same trait. Within-population diversity is expressed by differences among families that can be of the same magnitude as that between provenances both for adaptive and growth traits.

Taxus baccata, growing in Norway in the most northern part of its range, show population differences in genetic diversity most likely due to low level of gene flow and effects of inbreeding. In a study conducted in 2009, on the west coast of Norway, the most northern and marginal populations showed lowest level of genetic diversity. Nevertheless, recent experience shows that for the northernmost inland population of *Taxus baccata*, within-populations diversity still show quite high values for morphological traits like growing form and colour. No molecular data exist for this population, which is one of the dedicated genetic conservation units of the species in Norway

Lower level of genetic differentiation was found for *Malus sylvestris* which showed no reduction in diversity for the more northern populations. For *Fraxinus excelsior* fragmented populations along the west coast are the most genetically differentiated and the diversity is significantly decreasing northwards.

For the species we have genetic information from, there are large differences in genetic variation in quantitative traits both among and within populations. The level of molecular genetic diversity is largely shaped by their immigration history and the processes taken place along the migration routes. For some species there is a reduced genetic diversity in northern marginal populations.

Figure 10 Clouds of pollen from *Picea abies* stands. Photo: Ragnar Johnskås/ Norwegian Forest Seed Center

Table 5. Native forest tree species for which genetic variability has been evaluated at different genetic levels. The table is first of all based on information from NIBIO and the University of Bergen, and do not include all international studies where Norwegian material may have been included.

Species	Type of material evaluated [1)], genetic level	Morpho-logical traits	Adaptive and production characters assessed	Molecular characterization
Picea abies	provenances, families, clones	X	X	X
Pinus sylvestris	provenances, families	X	X	
Betula pendula	provenances, families	X	X	X
Betula pubescens	provenances	X	X	X
Betula nana	provenances			X
Alnus glutinosa	provenances, families	X	X	
Alnus incana	provenances	X	X	
Acer platanoides	provenances, families	X	X	
Fraxinus excelsior	provenances			X
Sorbus aucuparia	provenances, families	X	X	
Ulmus glabra	provenances, families	X	X	X
Malus sylvestris	provenances			X
Taxus baccata	provenances			X
Fagus sylvatica	provenances			X
Quercus petraea, Q. robur	provenances	X	X	
Corylus avellana	provenances	X	X	
Salix caprea	provenances	X	X	
Sorbus spp.	Populations, clones	X		

[1] Provenance = Trees from a defined geographic region
Population = Trees growing and reproducing in a smaller area
Family = Offspring from one mother tree
Clone = Genetically identical trees

The knowledge of intraspecific genetic variation patterns obtained in research is published in international and national research journals and in more popular national forest journals. It is also regularly disseminated at meeting and conferences for foresters. Major users, in addition to scientists, are the national tree breeding organisation and advisors in forestry and natural resource management at the regional and national level.

A survey was recently made of published studies of genetic variability of native Norwegian tree species, se Figure 11. Studies of birch, pine and spruce have been conducted since the beginning of the 1950s. In recent years we have increased knowledge of the genetic resources of other broadleaved species in Norway as a basis for better management of these.

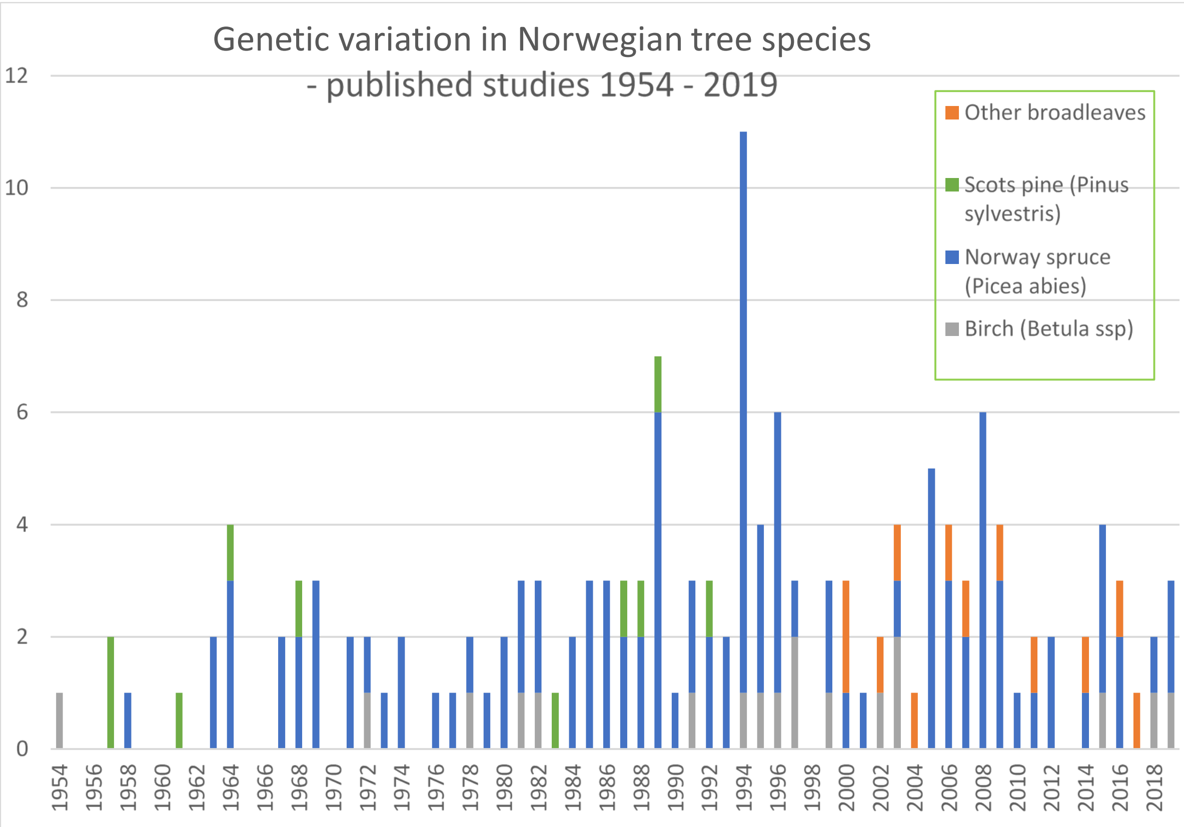


Figure 11. Number of published studies of genetic variability of native Norwegian tree species in the period 1954 -2019. Source: NIBIO

5.1.3 Exotic tree species

Trials with introduced conifer tree species have provided information about the genetic variability expressed in these species when growing in Norway. Genetic variability among provenances in adaptive and growth traits has been shown for *Picea engelmanni, P. glauca, P. mariana, Abies nordmanniana, A. amabilis, A. procera* and *Pseudotsuga menziesii*. For *Picea sitchensis, P. lutzii, Pinus contorta and Abies lasiocarpa* trials have shown genetic variation in adaptive traits and for growth both among provenances and among families within provenances. For the last species, which is cultivated for Christmas tree production, studies of molecular genetic diversity have been initiated.

5.2 Research plantations for long-term studies

Research plantations were often planted in experimental designs that were not suitable for long term studies, and few of the old trials exist to-day. During the last 50 years, most field trials have dealt with the most important native conifer, *Picea abies*, and many of these tests are kept and constitute valuable genetic resources containing genetic units from which genetic information on phenotypic traits is still available. The more recent trials with *Picea abies* were based on families from controlled crosses, and also some with clones, with the objectives of characterizing the genetic variability and inheritance patterns of the species, both within natural and in breeding populations.

Table 6 presents the number of field trials that are not part of the tree breeding activities. A large number of short term tests, often on agricultural soil and with an expected duration of less than 10 years are not included. The collections for *Sorbus spp*., *Salix pentandra, Juniperus communis* and *Ilex aquifolium* are part of collections of several trees species for landscaping purposes. Only the most numerous species are mentioned here.

Three institutions are mainly responsible for the field tests in forest genetic research: The Norwegian Institute of Bioeconomy Research (NIBIO), The Norwegian University of Life Sciences (NMBU) and The Norwegian Forest Seed Center.

A Nordic database of research field experiments with forest trees[3] lists 230 field trials in genetics and tree breeding in Norway, of which 160 are species or provenance trials, 63 are progeny tests and 4 are clonal tests.

[3] http://noltfox.metla.fi

Table 6. Native tree species stored in field collections in research or clone banks that are not part of the breeding programmes. Some of the accessions of *Sorbus spp*. will be overlapping between the collections. Source: NIBIO, Norwegian Forest Seed Center, NMBU & University of Bergen

Species; scientific name	Collections in provenance or progeny tests	
	No. stands	No. accessions
Picea abies	114	> 600
Pinus sylvestris	6	20
Betula pendula, ***B. pubescens***	6	> 100
Querqus petraea	1	17
Fraxinus excelsior	3	56
Fagus sylvatica	1	6
Sorbus meinichii	2	34/50
Sorbus hybrida	2	26/17
Salix pentandra	1	26
Juniperus communis	1	48
Ilex aquifolium	1	70

5.3 Challenges, needs and capacity-building

Generally, there is a lack of knowledge of the importance and implications of factors that may influence the genetic diversity of the forest tree species. Fragmentation of the landscape reduces the gene flow among individuals and populations which may lead to a smaller effective population size and increased degree of inbreeding. The gene flow among populations has been characterised for very few tree species with a fragmented distribution in Norway. For many tree species, regeneration is hindered by browsing of increasing population sizes of wild animals such as moose and red deer, e. g. browsing on *Taxus baccata*. Changes in land use and clogging influence the growth conditions, particularly for the hardwood broadleaved species, and may change the competitive environment.

Pests and diseases, which may be more common due to warmer climate at northern latitudes, may lead to loss of populations and thereby reduced diversity for some species. The implications of climate change on the forest genetic resources are not well understood, as the prediction of the future climatic conditions is uncertain. More information should be generated about the influence of these factors, and their interactive effects, on the forest genetic diversity.

Figure 12. Pest and diseases are likely to be associated with climate change. Ash dieback caused by the fungus *Hymenoscyphus fraxineus* has since 2006 spread through most of the distribution range of *Fraxinus excelsior* (common ash) in Norway.

Photo: Dan Aamlid/NIBIO

In general, prospects for future conditions are good, but pest and diseases, likely to be associated with climate change, and browsing pressure appear to be the main obstacles today. At present, genetic research related to the resistance of *Fraxinus excelsior* to the fungus causing the ash decline, with the aim of identifying resistant trees has high priority.

During the period 1950-1980 Central European provenances of *Picea abies* were planted to a large extent in southern Norway. Both practical experience and results from surveys showed that this was a bad choice of provenances for south-eastern Norway, resulting in plantations with climatic damage and reduced saw timber qualities. It was feared that gene flow from such stands would lead to a reduced adaptation in the next generation. Research results have shown that this may not be the case, as there seems to be a rapid change in adaptive performance from one generation to the next in Norway spruce.

During the years 2004-2008 a survey was conducted in five counties in Norway, to monitor the extent and regeneration of eleven selected marginal tree species. This was done as part of the national forest assessment. It was found that there has been an increase in the standing volume and area of several of the deciduous tree species. The data obtained from the survey is a good baseline for monitoring changes in the resources of these species, and a reassessment of the data has been initiated for a new five-year period from 2019. Connected to the ongoing reassessment, observations on disease symptoms on ash (*Hymenoscyphus fraxineus*) and elm (dutch elm disease) are included.

Further studies should be made of genetic diversity in natural populations to provide information for gene conservation activities, particularly of resistance against diseases.

Research in genetics of forest trees has a high priority in NIBIO. There is a close co-operation in breeding research between NIBIO and the Norwegian Forest Seed Center and scientists are recruited on this topic. More information about this in chapters 9 and 11.4.

6 *In situ* conservation of forest genetic resources

6.1 State of *in situ* conservation

The *in situ* conservation of forest genetic resources in Norway is still in development. During the last ten years work has started to conserve some of the most vulnerable forest genetic resources and tree species in different parts of their distribution range. In addition, *in situ* conservation for natural populations of Norway spruce, our most important commercial species, has been established. A plan for further conservation efforts and a project to assure knowledge based approaches is in place. *In situ* conservation will be further developed during coming years, to cover more species and to increase the number of areas for some of the existing species.

6.2 Approaches used for *in situ* conservation

In situ conservation of forest tree species comprises the conservation of viable populations in their natural environment, whether it is a production forest or a protected area. The term is often applied to naturally regenerating wild populations, and can be integrated into managed production and multiple-use forests. The aim of *in situ* conservation is often to conserve the function of an ecosystem and the evolutionary processes rather than just species. Under certain conditions, nature-protected areas provide a significant potential for *in situ* conservation of forest genetic resources.

Norway has chosen a strategy to establish *in situ* conservation units in protected areas for some target species. This is done as part of our national contribution to the common European project *Establishment of a European Information System on Forest Genetic Resources* (EUFGIS)[4][5], which has created an online information system for forest genetic resources inventories in Europe, focusing on improving documentation and management of dynamic conservation units of forest trees.

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 work on conservation of forest trees aims among other efforts to distribute *in situ* conservation areas within different climatic zones, using the zones (large scale selective environments) as proxies for adaptive diversity in the species.

6.2.1 Gene conservation units

Certain requirements have to be fulfilled on order for a protected area to qualify for being defined as a gene conservation unit (GCU). Minimum requirements for a given species will depend heavily on a number of factors including its reproductive biology and growth, ecology and kind of genetic threats it is currently facing or will most likely face in the near future. The requirements based on EUFGIS relate to population size, number of reproducing trees, sex ratio and whether trees are growing in stands or scattered. For each establishment, the conservation of the genetic resources must be in accordance with the original objectives for establishing the nature conservation area.

[4] www.eufgis.org (about the project)

[5] http://www.portal.eufgis.org/ (information portal)

Figure 13. **Crab apple (*Malus sylvestris*). A gene conservation unit (GCU) for *Malus sylvestris* has been established as part of a national park in the south of Norway in 2020.**

Photo: Per Arvid Åsen/Naturmuseum og botanisk hage, UiA

31 gene conservation units, in 24 different nature protection areas, comprising eleven forest trees species have been registered and are included in the EUFGIS database. They are shown in table 7.

The species occur differently and have different requirements for long term existence. As an example, *Picea abies* is a highly competitive species that occurs in large stands and with a sufficient sexual reproduction and natural regeneration capacity. Other species occur as scattered single trees that may have low competitive ability or insufficient sexual reproduction. Management plans have been established for some of the genetic resources, e.g for *Quercus, Taxus baccata* and *Malus sylvestris*.

A report from NIBIO (2014) emphasizes the need for incorporating conservation efforts for genetic resources in *Malus sylvestris*. In 2020, a GCU for *Malus sylvestris* has been established as part of a national park in the south of Norway.

Several Sorbus species are endemic to Norway; they often have marginal geographic ranges and some are considered threatened or exposed (Table 4, chapter 4.2). Many species comprise a large and often unique variation that needs special concern. Specific conservation activities are needed to manage and conserve these unique genetic resources. Based on former field studies 43 localities where these species occur with high variability or where rare taxa are found, have been identified and described. Some of these are in protected areas, some of which are designated for other purposes, but most are not. Protection and management are proposed for these localities, in some cases in a combination of *in* *situ* and *ex situ* conservation. It has been emphasised that important variation can be found within the species described. This variety can be just as important to preserve as the species itself.

Table 7. Forest tree species included in the in situ conservation programme. All conservation units established as part of the European EUFGIS project. Information about the protection areas and GCUs is available in NIBIOs mapping system, Kilden and in the European database EUFGIS.

Species	Number of conservation units (GCUs)	Total area (hectares)
Acer platanoides	2	46,9
Fagus sylvatica	2	46,5
Fraxinus excelsior	3	74,2
Ilex aquifolium	3	80,1
Malus sylvestris	1	29,2
Picea abies	5	13189,3
Quercus petraea	2	98,4
Quercus robur	3	104,6
Taxus baccata	3	118,4
Tilia cordata	3	253,5
Ulmus glabra	4	195,1

6.2.2 Protected areas in Norway

Protected areas in Norway are protected through The Nature Diversity Act from 2009. Excluding the marine reserves, there are four different types of protected areas, which differ in size, objectives (i.e. what is protected) and management regulations.

The four types of protected areas are:

1. National parks have been established to prevent activities that could disturb unspoiled areas of significant size, and also to protect landscapes and habitats for plants and animals. National parks also safeguard areas for outdoor activities, nature experience and recreation. Traditional farming and mountain dairy farming are usually allowed in a national park.
2. Nature reserves have the strictest protection regime among Norwegian protected areas. Some reserves cover untouched nature, while others are former cultivated land. A stated goal for these reserves is to conserve biodiversity, and vascular plants in particular, present at the time the reserves were established. However, when areas change as a result of succession, biodiversity will be affected, and management actions may be necessary to prevent loss of the species that initially were used for the selection of reserves. Activities that can impact the targeted protection objectives are strictly forbidden. Moreover, there should be management operations that can contribute to fulfil the objective for conservation of the specific area.
3. Protected landscape areas comprise distinctive and/or beautiful natural or agricultural countryside and often used to maintain actively used farming landscapes. Restrictions are less severe than in

other protected areas and farming and forestry can usually be continued, though with greater attention to not reducing landscape qualities.

4. The final type of protected area, biotope reserves, protects the ecological environment of specific plant or animal species, without protecting the corresponding area as a nature reserve.

Altogether 5 % of the total forest area is protected through one of the first two types of protected area. This allows the possibility to combine *in situ* conservation of genetic resources with other protection objectives in already protected areas. Nature reserves has been considered to form the most relevant option for *in situ* conservation of forest genetic resources because such areas are quite well documented as regards species content, size of area, the conservation regime is quite strict, development in such areas is to some extent monitored and some management can be allowed. In addition, a conservation unit for *Malus sylvestris* has been established in part of a national park in the south of Norway.

Apart from the dedicated GCUs, forest genetic resources are to a certain extend also protected in the nature reserves across the country. To monitor the general protection of forest tree species, a database of all protected areas in forests, and a listing of the tree species growing there, has been established by the Norwegian Genetic Resource Centre. The database includes information both on main and associated tree species and is linked to information in the national database of all protected areas managed by the Norwegian Environment Agency (Naturbase)[6]. The data on protected forest trees is open for public use through NIBIOs mapping solution *Kilden*[7].

During last years, the establishment of nature reserves in forest has increased, due to active political commitments aiming at 10 % protected areas in forests, as well as the development of a voluntary forest protection scheme. In this scheme, the forest owners themselves offer forest land for protection. If the area has environmental qualities that indicate protection and the environmental authorities accept the offer, the area can be protected as a nature reserve in accordance with Nature Diversity Act. An agreement will then be negotiated between the forest owner and the state, containing protection regulations and compensation. Work is ongoing to see if this scheme may be actively used also to establish additional GCUs for targeted forest trees.

Of the 2414 nature reserves in Norway in 2020, more than 1150 reserves are in forests, an increase from 412 in 2000 (Table 8).

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[6] https://kart.naturbase.no/

[7] https://kilden.nibio.no/?lang=nb&X=6786798.10&Y=98583.52&zoom=2&topic=arealinformasjon&bgLayer=graatone_cache&catalogNodes=716,725&layers=skogvern_verneomraader,skogvern_reservater,skogvern_bjork&layers_opacity=0.75,0.75,0.75

Table 8. **Nature reserves in forests in the years 2000, 2010 and 2019. Source: NIBIO, based on data from The Norwegian Environmental Agency (Naturbase).**

	2000		2010		2019	
Forest type	Number of reserves	Size hectares	Number of reserves	Size hectares	Number of reserves	Size hectares
Coniferous forest	189	79 086	438	261 554	779	441 998
Broadleaved deciduous forest	187	5 178	283	19 214	342	51 005
Taxus/Ilex forest	36	740	38	782	36	716

6.3 Organization of *in situ* conservation efforts

The Norwegian Genetic Resource Centre, with support from the Norwegian Environment Agency and the environmental authorities at the County Governor, is in charge of selecting suitable areas for *in situ* gene conservation for specific species, to be part of the EUFGIS network.

The Norwegian Genetic Resource Centre will initiate *in situ* conservation based on documented conservation needs in species, and an holistic assessment of how to ensure the necessary conservation measures.

The Norwegian Agricultural Agency plays a role as funding agency for gene resource projects, and have funded inventories in established conservation units for forest genetic resources. Management needs in the nature conservation areas, including for the management of genetic resources, have been funded by the environmental authorities.

6.4 Needs, challenges and opportunities

There is a need to further develop the establishment of gene conservation units for more species, including development of more specific climatic zoning combined with other relevant genetic information about individual species, to evaluate the genetic diversity conserved and where to proceed.

So far the establishment of GCUs in Norway has been in already established nature conservation areas. There is a need to cooperate closely with the environmental authorities and other relevant partners, to make forest genetic resources conservation part of the main target for future relevant nature protection areas, included in relevant regulations. There is an opportunity to take advantage of the ongoing voluntary forest protection scheme and increase the dialogue with environmental authorities and forest owners. It is important to obtain full acceptance from the nature reserve managers that the genetic resources of selected forest tree species should be conserved in protected areas and that management may be needed to fulfil also this objective of the protection. Such management should be an integrated part of the management plan for respective areas.

There is a question whether traditional *in situ* conservation efforts, as stated in the Pan-European strategy, are sufficient to secure the genetic resources against future challenges, including climate change, pests and diseases. We will work on an European level to further elaborate on this.

Hitherto there has been no systematic evaluation of how the existing GCUs established in Norway cover the species genetic diversity in the country. To prepare for further development of the conservation work, a project to evaluate the existing work and identify conservation gaps, as well as point at potential new conservation units has been initiated.

As part of the recent Horizon 2020 GenTree project, genetic characterization of the species *Fagus sylvatica, Quercus petraea, Taxus baccata, Picea abies, Pinus sylvestris* and *Betula pendula* has been done in five gene conservation units. The data provide very valuable data about the genetic status of the species in the units, data which in the future can be used in connection with genetic monitoring.

Regular monitoring of the existing conservation areas has been put in place and will start in 2020. Some management activities are still hard to prioritise in the units, due to lack of resources and means.

Greater public awareness is needed about *in situ* conservation of vulnerable tree species and the role of protected areas for such conservation. Information about this function of each specific reserve should be given, and the on-line national database of protected areas, Naturbase should be updated with this information.

6.5 Priorities for capacity building and research in this area

In the first selection of conservation units (2007-2013), the most vulnerable species were selected, in addition to Norway spruce (*Picea abies*). The vulnerability analysis was based on Myking (2002). In 2019, the Genetic Resource Centre has published a plan for conservation, which comprises more species and aiming for additional GCUs in other geographical areas for the species which are already conserved. A project on “Knowledge base for selecting new conservation areas for forest genetic resources” has been established in 2020, to ensure that the development of conservation is in line with current knowledge, e.g. establishing more detailed climatic zoning to assess adaptive diversity conserved.

Norway will continue an active involvement in Nordic and European projects and cooperation on forest genetic resources, to strengthen our common efforts on *in situ* conservation.

7 *Ex situ* conservation of forest genetic resources

7.1 State of *ex situ* conservation efforts

Ex situ conservation of forest genetic resources in Norway is performed in *ex situ* conservation stands and in seed storage.

Ex situ conservation of forest genetic resources with a long-term perspective and a plan for proper regeneration has so far only been prioritised for a few species in Norway. *In situ* conservation is the preferred conservation form for the vast majority of our forest trees, because it provides a dynamic conservation that facilitates evolution and natural adaptation to changes in the environment and climate. Much of the *ex situ* conservation measures which are put in place, are connected to the commercial species, Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). For some marginal species and populations, long term *ex situ* measures have been proposed to serve as complementary to or instead of *in situ* measures, but so far not implemented on long-term basis.

Information on research plantations; progeny tests, clonal archives and seed orchards belonging to the national breeding programme is further elaborated in chapter 8.

Several arboreta and botanical gardens possess collections of forest trees, of both native and exotic species. In most cases these collections contain a small number of individuals of each species and do not have a strategy for long term regeneration. Therefore, they are not considered as elements of the national conservation strategy. Such collections often contribute to the maintenance of unique and rare genotypes, but may also contain locally adapted populations of native species and individuals from transferred provenances of native or exotic species. Collections of trees in arboreta often have a role as public parks and are important for raising public awareness.

7.2 Approaches used for *ex situ* conservation

7.2.1 *Ex situ* conservation stands

Since 2018, dynamic *ex situ* conservation stands for forest genetic resources have been established in eight planted Norway spruce stands in Eastern Norway, in cooperation between the Norwegian Genetic Resource Centre, The Norwegian Forest Seed Center 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. There is an agreement with the forest owner, that seed may be collected before eventual logging, to assure that the genetic resources are kept, and to facilitate proper regeneration of the stand.

Figure 14. Dynamic ex situ conservation stand in Rena, Eastern Norway.

Photo: Jo Petter Grindstad/Glommen Mjøsen Skog

7.2.2 Seed storage

In 2015, seed samples of Norway spruce and Scots pine, were deposited and stored in Svalbard Global Seed Vault (SGSV), as part of a Nordic collaboration. The SGSV is owned by the Norwegian government and managed and operated in a partnership between the Norwegian Ministry of Agriculture and Food, the Nordic Genetic Resource Center and the Global Crop Diversity Trust. The aim of the initial storage of forest tree seeds at the Seed Vault has been:

- Back-up storage for conservation of seed samples from different stages and generations of breeding populations or seed orchards to monitor changes in genetic diversity taking place during breeding operations

It has been discussed whether such long-term seed storage could serve other purposes also, for instance back-up storage of samples from natural populations for future monitoring and conservation of threatened populations.

The Norwegian Forest Seed Center has established a biobank as part of their activity. The biobank includes DNA samples and about 770 reference seed samples of spruce and pine. These are seeds from all seed lots which were available about 10 years ago. The purpose is to have seeds available from all produced lots as a reference for experiments and research. The seed lots stored at Svalbard represent a representative selection of these reference samples.

7.3 Needs, challenges and opportunities

Only very few of the *ex situ* approaches are true long-term conservation efforts. The *ex situ* conservation stands established for conservation of important breeding material from the plus trees should be further developed. Strategies for *ex situ* conservation of genetic resources of species threatened by diseases should be developed.

8 The state of use

Forest genetic resources in Norway are used in production forestry when forests are regenerated after harvest, in afforestation on treeless land or for the replacement of other tree species. They are also used for Christmas tree production, for landscaping purposes or for ornamental use in parks and gardens.

The Forestry Act requires that regeneration generally should take place within three to five years after harvest, depending on environmental conditions. The local forest authority is mandated to demand that the forest owner takes actions to establish a commercially viable stand within a reasonable period. Regulations are given for silvicultural and environmental actions in the regeneration, such as choice of tree species, introduction of exotic species, the transfer of provenances and the recommended number of seedlings planted per hectare.

In production forestry, regeneration after harvest is executed differently for the two major commercial species, *Pinus sylvestris* and *Picea abies*. *Pinus sylvestris* is to a large extent naturally regenerated, using the seed-tree method. In the regeneration fellings, 30-150 seed trees are retained per hectare, depending on site conditions. Recently, there has been a renewed interest in planting *Pinus sylvestris* seedlings, and genetically improved materials from the Swedish tree improvement program are being used.

Figure 15. Seed trees of *Pinus sylvestris* left for natural regeneration.

Photo: Sverre Skoklefald/NIBIO

Picea abies is regenerated both naturally and artificially by planting. When natural regeneration is planned, the use of patch clear-cuts and shelter wood fellings are common. When using the latter method, 150-400 trees are retained per hectare for seed dispersal and to provide shelter. The shelter trees can also be other tree species than *Picea abies*. At higher elevations, a significant proportion of the spruce forest is also harvested by means of mountain forest selective cutting, where subsequent recruitment is initiated by either natural regeneration or planting, or a combination of both. However, clear-cut fellings and subsequent planting of seedlings is most common in *Picea abies* and is considered the fastest regeneration method on most forest sites. In assessments made, approximately 75 % of the planted areas had a seedling density equal to or higher that that recommended in the legal regulations.

For *Picea abies*, forest reproductive materials are available in sufficient amounts both from natural and cultivated forest stands and from the tree improvements program. The use of the forest genetic resources of *Pinus sylvestris* is primary based on seeds from the natural forest, but to some extent on genetically improved material. Reproductive materials are also available for some broadleaved tree species, in particular for *Betula pendula* and *Alnus glutinosa*.

8.1 Reproductive material in use

The number of seedlings delivered from Norwegian forest nurseries and planted in production forestry were strongly reduced 15 years ago but are now close to the numbers of seedlings planted 20 years ago, as shown in Figure 16. Of the 44.5 million seedlings delivered from the nurseries in 2019, 98 % were *Picea abies*. In addition, around 2 million *Picea abies* seedlings and 1 million seedlings of *Pinus sylvestris* were imported.

The seedlings are produced in nine forest nurseries in different parts of the country, owned by seven companies. In general, each nursery produces seedlings for its local region. Most of the seedlings are one- or two- year-old container plants.

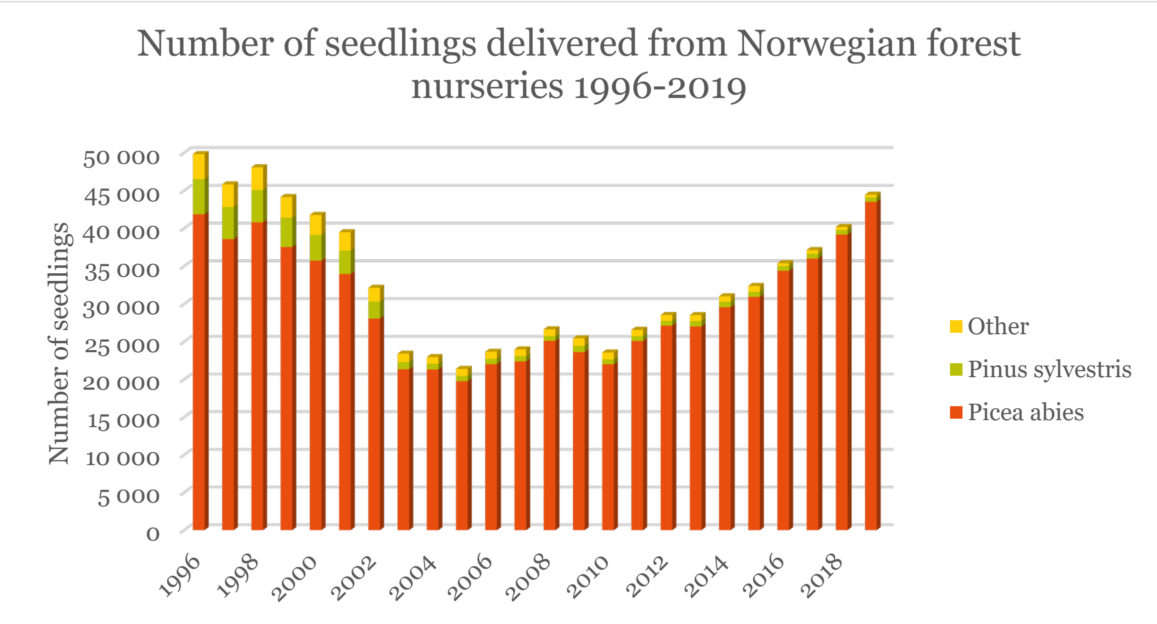

Figure 16. Number of seedlings, in unit of 1 000, delivered from Norwegian forest nurseries 1996-2019. Source: The Norwegian Forest Seed Center.

The seeds used in the forest nurseries are delivered by the Norwegian Forest Seed Center. This organisation is also responsible for the tree breeding activities. Table 9 presents the mean annual weights of seeds sold, by species, of domestic sources and imported and exported, as an average of the two years 2017 and 2018. The dominating species is Norway spruce, covering 96 % of the overall domestic seed sale and for purpose of timber and pulpwood production.

Table 9. Mean weight of seed sold domestically and transferred internationally for the years 2017 and 2018. Source: The Norwegian Forest Seed Center.

Species		Weight of seed Kg			Purpose (relates to columns domestic seed sale and import, not export)
Scientific name	Native (N) or exotic (E)	Domestic seed sale	International transfer		
			Import	Export	
Picea abies	N	326.2		16.3	Forestry; timber and pulpwood
Picea abies	E	8.7	20.3		Forestry; timber and pulpwood
Pinus sylvestris	N	4.5		0.5	Forestry; timber and pulpwood
Pinus sylvestris	E	0.7	8.6		Forestry; timber and pulpwood
Abies lasiocarpa	E	5.7		0.1	Christmas trees
Other conifers		4.6		0.5	
Quercus petraea				35 020	
Other broadleaves	N	0.05		0.17	Forestry and landscaping

Forest reproductive materials are in Norway classified in the categories of the OECD Forest Seed and Plant Scheme: source-identified, selected, qualified and tested. Import of seeds of *Picea abies*, which was quite high 50 years ago, is now at a low level. Figure 17 shows the development in the sale of seeds from source identified and selected (stand seed) and seed orchards. The percentage of seeds from seed orchards has increased considerably during the last years and seed orchard seed in 2017 and 2018 amounted to 91 % of the *Picea abies* seed sold, and with a percentage close to 100 in south-eastern Norway. These years, 25 % of the Norway spruce seeds sold was from the tested category.

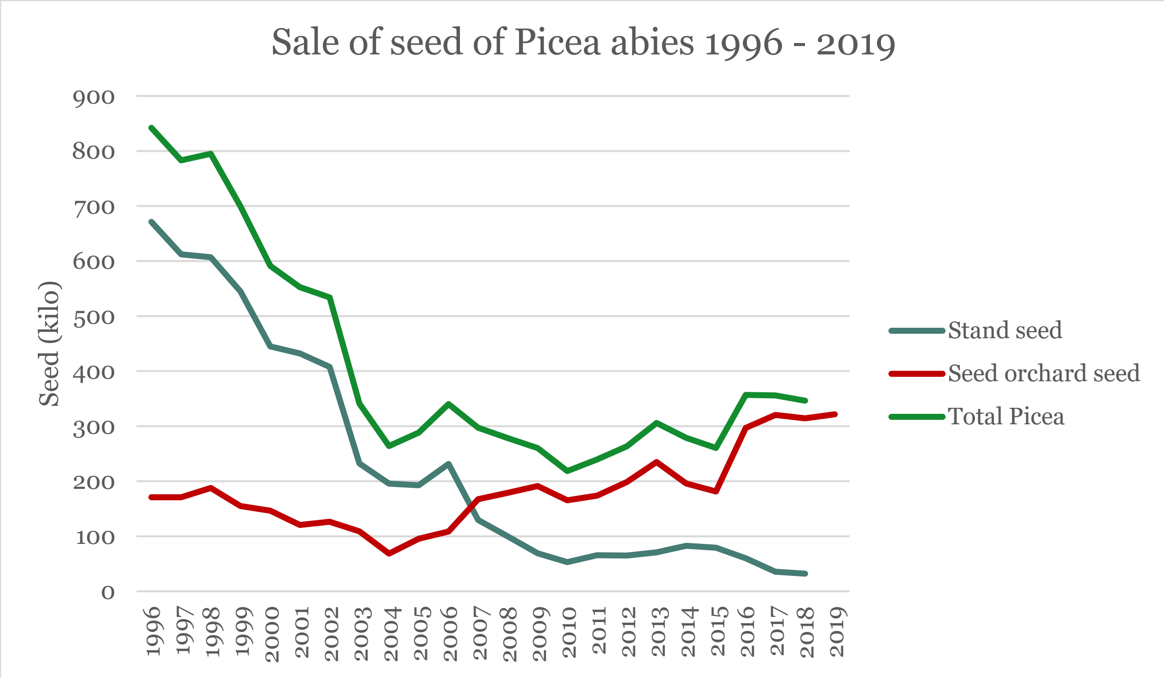

Figure 17. Sale of seed in kg of *Picea abies* 1996-2019, distributed in classes of stand seed and seed orchard seed. Source: Norwegian Forest Seed Center

A national designated authority, The Control Committee for Forest Reproductive Materials in Forestry, appointed by the Ministry of Agriculture and Food, oversees that the intentions and rules in the regulations related to forest reproductive materials are being followed.

It is the policy of the Government that the use of exotic tree species should be restricted in forestry. A permit is therefore required from the local environmental authority before establishing plantations based on forest reproductive materials of non-native tree species. All import of forest reproductive materials should be approved by the Control Committee, taking the origin and the intended area for use of the materials into account. Adaptation of the materials to the climatic conditions has high priority.

8.1.1 Regions of provenance and transfer rules

In the past, most reproductive material of *Picea abies* was of the category source identified, collected in natural stands and characterized by its region of provenance. According to a regulation on forest plants and forest seeds mandated in the Forestry Act, transfers within the country should not be made more than 200 km north or south and less than 300 m in altitude. The Norwegian Forest Seed Center provides recommendations for the use of materials from national seed orchards. During the last 40-year period, the far largest part of *Picea abies* seed used has been from sources of native origin. However, in western Norway, where *Picea abies* did not occur naturally, provenances from Central Europe are recommended due to their superior volume growth in the coastal areas.

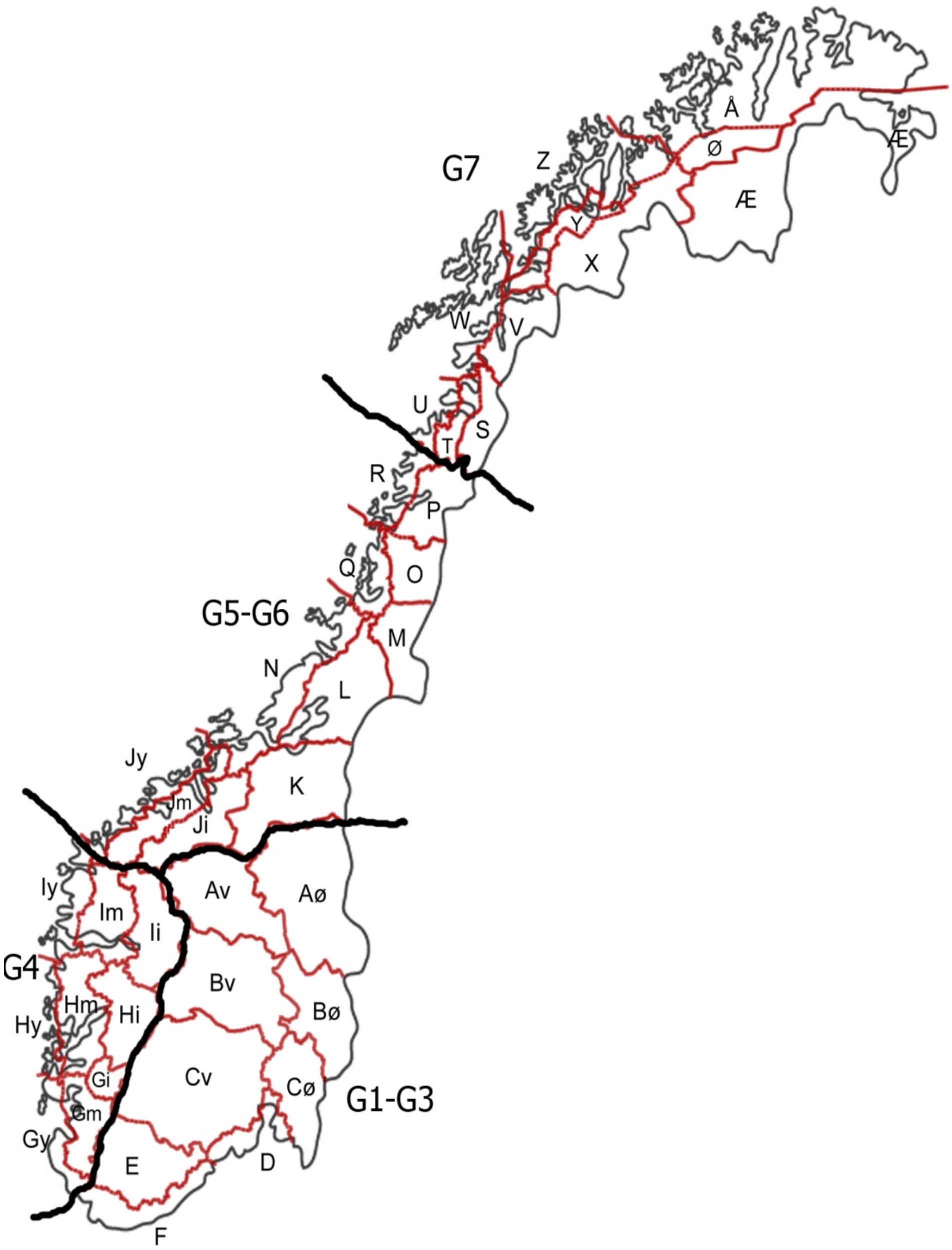

Figure 18. Regions of provenance in Norway (red borders) and breeding zones according to the revised breeding strategy from 2010. The regions of provenance are in addition characterised by the altitude in 100 m intervals. Source: The Norwegian Forest Seed Center

8.1.2 Forest reproductive materials

The Norwegian Forest Seed Center is responsible for the procurement, storage and trade of seeds for the forest sector. Seeds of recommended seed sources and of both native and imported species are stored, with main emphasis on a wide selection of native *Picea abies* provenance and seed orchard seed lots and *Pinus sylvestris* provenances, as shown in Table 10. Seed years are scarce at northern latitudes and at high altitudes. Seed lots are therefore kept as long as 20-30 years until new representative seed crops become available. Optimal storage conditions will guarantee a high germination rate even after several decades of storage. This seed storage is an important component in the management of the forest tree genetic resources in artificial regeneration. Samples of some seed lots of native species are saved for long term storage. Documentation and information about available seed lots stored at The Norwegian Forest Seed Center is available at the home page of the institution for registered users.

Table 10. Number of accessions of commercial seed lots of forest tree species stored at The Norwegian Forest Seed Center. Seed lots of OECD category source identified are available for all species and for some species also categories qualified or tested. Seed reserve accessions (collected prior to 1996 and non-commercial quality) of Norway spruce and Scots pine are not included in this list. Source: The Norwegian Forest Seed Center

Native species	Number of accessions	Exotic species	Number of accessions
Alnus incana	2	*Abies amabilis*	1
Alnus glutinosa 1)	1	*Abies bommulleriana*	1
Betula pendula 1)	6	*Abies fraseri*	1
Betula pendula carelica	2	*Abies koreana*	3
Picea abies 2)	90	*Abies lasiocarpa* 1)	10
Pinus sylvestris 1)	79	*Abies nordmanniana*	1
		Abies procera	9
		Abies veichi	1
		Larix decidua	1
		Larix kaempferi	2
		Larix sibirica	1
		Picea omorica	1
		Picea sitchensis 1)	3
		Pinus cembra	1
		Pinus contorta 1)	2
		Pinus mugo	4
		Pseudotsuga menziesii	2
		Thuja occidentalis	1

1) qualified 2) qualified or tested

8.1.3 Materials for landscaping purposes

A substantial number of trees of both native and exotic origins are planted in the landscape; in parks, along the roadside and in private gardens. Cultivars and clones with specific aesthetic values have been developed, tested and propagated for use in such plantings. For Norwegian conditions, testing for frost hardiness is of specific importance, but also other climate damages, as well as growth and esthetic qualities. Collections of such materials, intended both for testing and demonstration purpose, contain valuable genetic resources. They offer a large variety of genetic materials and contribute towards increasing the diversity of tree plantings in the landscape. The largest collection, located at NMBU, contains trees of approximately 120 different species. However, only a small number of trees of each genetic unit has been planted, in most cases four.

A part of the collection are native tree species of the genera *Acer, Alnus, Betula, Fraxinus, Juniperus, Picea, Pinus, Prunus, Quercus, Salix, Sorbus, Taxus* and *Tilia*. This part of the collection has been developed to increase the use of native tree species in plantings, to ensure a broader genetic material for use and to serve as alternatives to exotic material which could be regulated under the legislation on alien organisms. The result is an increasing number of native plant material (seed sources and clones/varieties) which is under development and is fully or partially available for landscape purposes or ornamental use, through nurseries and other producers of plants. Figure 19 gives an indication of the development of this work since 2012.

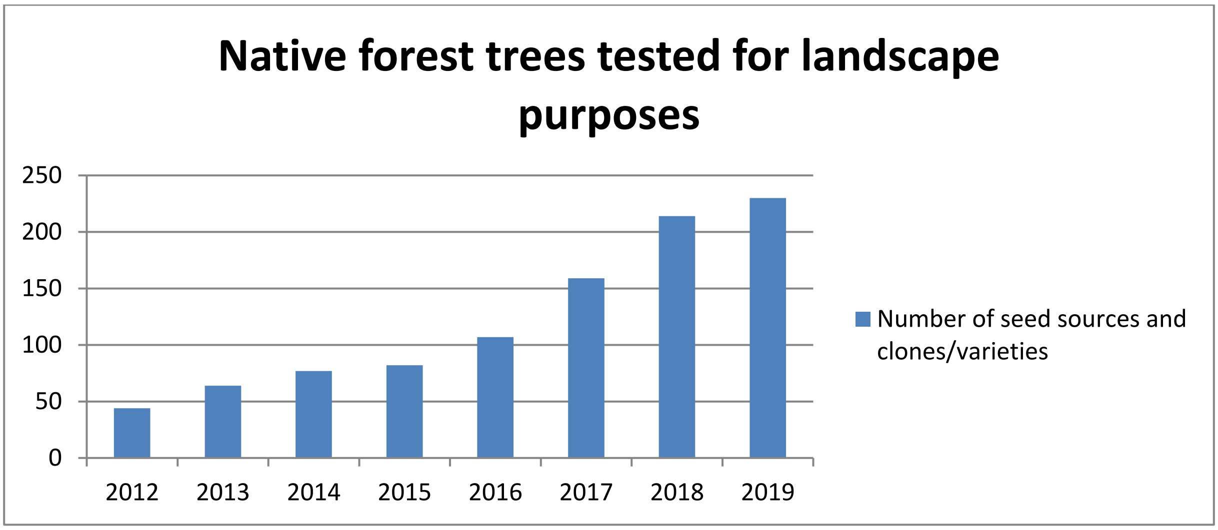

Figure 19. Number of seed sources and clones/varieties of native forest trees that are under development and which are fully or partially available to nurseries for landscape purposes or ornamental use. The Norwegian Landscape Laboratory at NMBU is a demonstration and testing area for relevant tree species for revegetation and planting in gardens and landscape. The main goal of the work is to enable a good basis for recommending suitable clones and seed sources for ornamental purposes and revegetation. Source: NMBU

Since 2019, a conservation agreement exists between NMBU and the Norwegian Genetic Resource Centre in NIBIO, to assure long term conservation of the forest genetic resources in native tree species in the collections.

8.1.4 Needs, challenges and opportunities

An increased interest in Norwegian forestry to plant *Pinus sylvestris* will require efforts to produce larger quantities of seedlings of this species, either by seed collection in forest stands, by tree improvement activities of by import of genetically improved materials.

An effective use of forest reproductive materials should be based on knowledge of the performance of different materials and matching their adaptive properties to the site conditions. Efforts are being made to develop models for the deployment of forest reproductive materials of *Picea abies*, and possibly *Pinus sylvestris*, adapted to specific climatic conditions, both for present and for future climatic scenarios. Such models will be used to establish a web tool for the recommendation of optimal reproductive materials for specific site conditions.

There is a need to further develop and offer well adapted reproductive materials of woody plant species for planting in the landscape, parks, along roadsides and in private gardens.

9 The state of genetic improvement and breeding

9.1.1 Tree breeding in Norway

Tree breeding activities in *Picea abies* started in Norway more than 70 years ago with the selection of plus trees in natural stands, and grafted seed orchards were established in the 1960s and 1970s. Breeding activities were also initiated with other conifer species (*Pinus sylvestris*, *Picea sitchensis*), but with a lower intensity than for Norway spruce. The selected plus trees were kept as grafts in the seed orchards or clonal archives, and a progeny testing program was slowly initiated. Series of progeny trials where later established to estimate breeding values of the plus trees, as basis for selection and establishment of new seed orchards and the long-term breeding population. Tree improvement activities have been performed for ten forest tree species (including some introduced species), which materials and trials are presented in Table 11. For the species with highest priority, *Picea abies*, 150 trials with a total of 3800 families are in the breeding programme.

Table 11. Tree improvement materials and trials. 1) More trees were originally selected, these are the plus-trees available as grafts or in families. 2) The number of unique families. Source: The Norwegian Forest Seed Center.

Species		Plus trees	Clonal archives	Provenance trials		Progeny trials	
Scientific name	**Native (N) or exotic (E)**	**Number**	**Number**	**Number of trials**	**Number of provenances**	**Number of trials**	**Number of families**
Picea abies	N	4900 1)	26			150	3800 2)
Abies lasiocarpa	E		1		76	10	80
Alnus glutinosa	N	100		9	11	1	121
Pinus sylvestris	N	150	4	7	40	0	0
Picea sitchensis	E	168				2	6
Picea lutzii	E	50				17	213
Picea engelmanni	E	76				1	15
Pinus contorta	E			1	11	1	99
Larix sibirica	E	22					
Betula pendula	N	200		5	15	1	225

The species involved in the present breeding programmes, their priority and the number of seed orchards are listed in Table 12. An increasing number of the orchards will soon be in the tested category. In addition to breeding for timber and pulpwood, Christmas tree production is an important objective. Main priority in breeding is given to *Picea abies* and *Abies lasiocarpa*

Table 12. Species and seed orchards in the tree improvement activities in Norway in 2020. Seed orchards are of 1, 1.5 and 2nd generation. Source: Norwegian Forest Seed Center.

Species	Native (N) or exotic (E)	Improvement programme Objective	Priority	Seed orchards	
				Number	Area (ha)
Picea abies	N	Timber and pulpwood, Christmas trees	High	17	109.7
Abies lasiocarpa	E	Non-wood forest product, Christmas trees	High	4	9.1
Alnus glutinosa	N	Timber and pulpwood, landscaping	Medium	2	1.0
Picea lutzii	E	Timber and pulpwood	Low	1	1.9
Pinus contorta	E	Timber and pulpwood	Low	1	3.4

A revised national tree breeding strategy for the period 2010-2040 was approved in 2017, after an open consultation process involving organisations in practical forestry, environmental management, forest authorities at national and local level, research organisations and universities. It will be revised at ten-year intervals, and five-year action plans will be made for each breeding zone. The strategy has been thoroughly described also in the current white paper on forest policy from 2016.

In the breeding programme for *Picea abies*, Norway is divided into eight breeding zones (Table 13) based on latitude, altitude, and known climatic gradients, both for administrative reasons and optimal use of adapted reproductive materials from the seed orchards. Breeding efforts and objectives differ between zones depending on whether there are specific issues in the wood production that must be focused, and on the importance of forestry in the region. In each zone the breeding population is divided into one or more sub-populations each containing 50 unrelated individuals. Breeding zone G0 will contain one sub-population with individuals selected from more southern provenances adapted to climatic conditions corresponding to a 2° C increase in mean annual temperature in zones G1 and G4. The other zones will contain sub-populations with individuals from a limited geographic area within the zone. Hence, the populations should then be adapted to the present climate in the zone, but may also be ranked according to climatic gradients within the zone. They should provide the basic material for producing reproductive material from seed orchards that could be used in a wide area, but also be flexible for transfer under climate change conditions. All individuals in the sub-populations should be tested in progeny tests planted at several sites.

Table 13. Breeding zones and regions of deployment for Picea abies in Norway. In each breeding zone there are one or more sub-populations each containing 50 unrelated individuals from a limited geographic area within the zone.

Breeding zone	Region of deployment	Altitude	Number of sub-populations
G0	Same as G1 and G4 with a 2º C increase in mean annual temperature	0 – 250 m	1
G1	Interior south-eastern Norway Lat. 58º - 62º N	0 – 350 m	5
G2	Interior south-eastern Norway Lat. 58º - 62º N	350 – 650 m	4
G3	Interior south-eastern Norway Lat. 58º - 62 ºN	650 – 950 m	4
G4	Western Norway Lat. 58º - 62 ºN	0 – 350 m	2
G5	Central and northern Norway Lat. 62º - 66º30'N	0 – 250 m	3
G6	Central and northern Norway Lat. 62º - 66º30'N	250 – 550 m	3
G7	Northern Norway Lat. 66º30' - 70ºN	0 – 250 m	1

It is important to note that breeding and deployment zones are different and that there can be several deployment zones within each breeding zone. The deployment zones are defined by the adaptive properties of the seedlings from each seed orchard which must be tested. Their performance will to some extent be influenced by the seed orchard locality due to both pollen contamination from surrounding forests and by epigenetic effects caused by the climatic conditions at the seed orchard site.

The importance of traits in selection will vary among zones, but will generally characterise annual growth rhythm, height growth and wood quality traits. The timing of flushing in spring is a key trait in regions where spring frosts frequently occur, and early flushing will be avoided.

The aims of the breeding programme are to produce seed with better traits for volume production and CO^2 -sequestration, wood quality and climatic adaptation, without deteriorating the genetic variation. The bred material should thus have a higher survival and possibly, be used over larger areas than material from natural stands. The new seed orchards are expected to have a genetic gain in volume production of 20 % or more.

The earliest established seed orchards of *Picea abies* are now terminated or are re-established with parents that are being tested in the progeny tests. Thus, the first round of seed orchards is now being replaced by 1.5 generation orchards (selection of plus trees based on their breeding values) and 2nd generation (selection from progeny trials) seed orchards. The recommendations for the deployment of reproductive material should be revised as more knowledge exists from field tests.

The national tree breeding programme is organized by the Norwegian Forest Seed Center which is responsible for all breeding activities and is in addition the national institution for seed trade in forestry. Recently, three breeding centers have been established, in Central, Interior and Southern Norway. Here, local activities will have priority. The breeding programme is partly financed by the Ministry of Agriculture and Food and by added cost paid by the users of seeds and seedlings compared to non-bred materials originating from forest stands.

The use of high-quality seeds and seedlings is highly recommended, and measures are taken to ensure that the tree planters actually use the materials. All information about reproductive materials available is presented at the website of the Norwegian Forest Seed Center. Advice is given for recommended materials for a planting site defined by region and community, latitude and altitude. It is planned that nurseries producing seedlings of the different seed lots for sale will be listed. Research results important for breeding and for motivating the foresters to use these materials are presented in popular form both by the Norwegian Forest Seed Center and NIBIO.

9.2 Challenges and opportunities

Some initiatives concerning potential breeding activities for *Pinus sylvestris* and *Betula pendula* has started. Work is ongoing at the Norwegian Forest Seed Center to follow up on these. A beneficial cooperation exists among the tree breeding organisations in the Nordic countries.

Research in genetics and genomics, as well as in breeding has and will provided new knowledge and techniques to be used in the applied breeding programme:

- The use of a centralized biobank to store DNA samples and seed lots for future use
- The use of molecular markers/genomics to identify materials in the breeding populations and for identifying genes controlling traits that are important in selection
- The use of molecular markers to identify and genetically evaluate large number of trees originated from regular forest stands for inclusion in the breeding population, using the "breeding without breeding" approach
- Testing and implementation of genomic selection to predict breeding values
- The use of drones to measure tree heights in forest stands and in progeny trials
- The use of databases for secure and efficient storage of all information generated in the breeding population and associated trials

Figure 20. ***Picea abies*** **seed orchard (left). Short term progeny test with** ***Picea abies*** **on cultivated soil (right). Photos: Ragnar Johnskås/Norwegian Forest Seed Center and NIBIO**

10 Management of forest genetic resources

10.1 State of management

The forests in Norway are managed in accordance with the goals of sustainable forest management. The online version of the "Sustainable Forestry in Norway" report[8] contributes to the debate on forestry, making it easier to access fact-based information about status and management of Norwegian forests. The report includes a chapter on forest genetic resources.

Forest management plans are important tools for the forest owner, in order to promote sustainable forest management. This includes both active commercial use of the forest resources as well as the forest owner's responsibility for the protection of biological diversity, landscapes, recreation and cultural values in the forest. Forest management plans are offered to all forest owners in Norway every 10th to 15th year according to plans at county level. Providing an inventory of forest resources and environmental values on the property is a precondition for the allocation of grants. A regulation under the Forestry Act requires forest owners to reinvest a part of the revenue from forestry into a government administrated fund; the Forest Trust Fund. From the genetic resource point of view, this fund has in particular been important for contributing to the reestablishment of forests after harvest with proper reproductive materials.

All seedlings delivered from the nurseries since 1998 are part of a national reference system, which would tell the forest owners and managers from which seed source the material comes. This means that if this information is kept, it would be possible to monitor the development of the stands and how the specific seed sources cope with different environments. However, there are so far only insufficient registers that link the reference number to the specific planted forest stand. Experience indicates that communication about what the reference number is and why it is important is lacking.

Since the beginning of the 1950s work has been conducted to document genetic variation and genetic traits in forest trees. This is the basis of all targeted work on sustainable use and conservation of forest genetic resources, and is further explained in previous chapters. However, there is a focus mostly on only a few species. There is a need to increase genetic knowledge in general, to assure targeted conservation of native tree species.

There is a high level of concern that the breeding programme ensures adequate genetic variation in the breeding population. To ensure sustainable breeding of *Picea abies* with enough genetic variation in the bred material, a three-year research project on genetic variation in planted forests has been completed in 2018.

Invasive damaging agents, both species which have already established and species which may migrate to Norway in the future, are potential challenges to the management of future forest resources. NIBIO has developed an online tool to monitor all plant health related damages in forest trees[9]. The online tool provides an overview of the occurrence of such damages, as well as information about more than 200 different types of damaging agents and the possibility to report any live observations.

[8] https://www.nibio.no/en/subjects/forest/sustainable-forestry-in-norway?locationfilter=true

[9] www.skogskader.no

10.2 Needs, challenges and opportunities

Climate change poses mitigation and adaptation challenges. Forest reproductive material can be used effectively to ensure the production of biomass as a replacement for fossil fuels and as a carbon sink. At the same time, however, we must conserve the ability of forests to adapt to currently unknown threats and to maintain a high-level provision of ecosystem services. This requires striking a balance between using small numbers of selected genotypes and using broader populations which secure genetic diversity and thus adaptability.

Studies of genetic variation in the forest are the basis for proper management of the genetic resources in forest trees. It is therefore important to focus on further developed and increased characterization and documentation, both to evaluate the degree of genetic diversity and to identify potential production traits. Adaptation to climate change, including pests and diseases is fundamental for a sustainable management of forest genetic resources.

In order to have a good overview of which seed lots, and thus which genetic resources, are planted in different forest stands in Norway, it is important that the system of traceability of forest material is improved. The more information there is on which seed sources are planted in the forest, the better the monitoring on how different genetic material adapt to changing environments and climates. In the long run, this will ensure better knowledge for breeders and managers.

There is a potential to increase the use of broadleaves and mixed stands in production forest in Norway. Facing climate change, it may be necessary to widen the scope of tree species in production.

Phytosanitary regulations need to be effective to prevent the introduction and spread of forest pests and pathogens via transport and trade. Awareness should be raised among professionals, forest owners and policy leaders. Existing phytosanitary regulations should be continuously updated with science-based knowledge.

Further, knowledge on the qualitative and quantitative impact on FGR from silviculture, e.g. how does thinning and clearing influence genetic material in both naturally regenerated and planted stands, need to be further elaborated by research.

11 Institutional framework

11.1 National coordination mechanisms and partners

The Norwegian Genetic Resource Centre was established in 2006, as part of NIBIO. The existing national programmes for animal, plant and forest genetic resources were merged in the centre.

The Norwegian programme on forest genetic resources was initiated in 2001. A national FGR advisory committee was appointed by the Ministry of Agriculture and Food, with a secretariat hosted at NIBIO (previously called Norwegian Forest Research Institute). Nordic coordinated work on forest genetic resources was ongoing since 1970.

Apart from the Norwegian Genetic Resource Centre and NIBIO, several other institutions are dealing with forest genetic resources, among those are the Norwegian Forest Seed Center, national and regional authorities for agriculture and environment, representatives of the forest sector and research institutions.

11.1.1 The Norwegian Genetic Resource Centre

The Norwegian Genetic Resource Centre promotes the conservation and sustainable use of national genetic resources in farm animals, crop plants and forest trees. It is the national centre of expertise on genetic resources in agriculture, advisory to the Ministry of Agriculture and Food, and coordinates a wide range of activities.

The Centre is responsible for monitoring and reporting on the state of conservation and sustainable use of forest genetic resources, as well as initiating activities in cooperation with partners. The Centre has expert responsibility for developing the national action plans for genetic resources in farm animals, crop plants and forest trees. The Centre contributes towards increasing the information flow and general public awareness. It is also the national participant in Nordic and international programmes.

The Genetic Resource Centre is financed under the budget of NIBIO funded by the Norwegian Ministry of Agriculture and Food, amounting to approximately 6 million NOK per year. Of this amount, 1 mill NOK is financing approximately a 60 % position responsible for forest genetic resources.

11.1.2 Priorities

The national programme for forest genetic resources runs in four-year cycles. In the last period 2016-2019 the following activities were given high priority:

- Documentation of knowledge about national FGR in natural habitats
- Climate adaptation and monitoring of trends and risks for FGR
- Monitoring the genetic resources of selected broadleaved tree species in the regular sample plots of the National Forest Inventory
- Updating databases of protected areas containing populations of forest trees species
- An holistic plan for conservation of forest genetic resources, *in situ* and *ex situ*, and further develop *in situ* conservation of FGR in protected areas
- Dynamic *ex situ* conservation of valuable breeding material
- Promotion of *ex situ* conservation and use of national FGR in horticulture and revegetation

- Sustainable breeding of *Picea abies*
- Public awareness activities
- Nordic and international cooperation on FGR

The existing action plan for conservation and sustainable use of forest genetic resources is expected to be revised during 2020. The actions are based on the Global Plan of Action for FGR, and divided in four major areas:

- Documentation and monitoring
- *In situ* and *ex situ* conservation
- Sustainable use and development of FGR
- Networking, coordination and dissemination of knowledge about FGR

11.1.3 Partners

Accomplishment of the national program and action plan is highly dependent on synergies and close cooperation with a broad range of partners. The partners and their related tasks can be summarised in Table 14.

An advisory committee for forest genetic resources consisting of representatives of different actors relevant for FGR in Norway has been active till 2019. The aim was to secure a broad scope and anchoring of the national FGR-activities. As of January 2020, the committee as such is no longer active, in line with revised organisation of work.

The national funds for genetic resources activities were previously under the responsibility of the advisory committees on genetic resources and the Norwegian Genetic Resource Centre. Since 2016 the Norwegian Agriculture Agency has taken over the role as financing body for implementation of the action plans. Thus, there is a shared responsibility between the Agency and the Norwegian Genetic Resources Centre for management of genetic resources for food and agriculture. The Agency's primary objectives are management of financial and legal instruments connected to the agricultural sector, including forestry. The Agency will contribute to the implementation of the national strategy on genetic resources.

Since 2020 the regional authorities at the county governor have been given an increased role in genetic resource management. The county governor will implement the national strategy for the conservation and sustainable use of genetic resources for food and agriculture, including:

- integrate the concern for the conservation and sustainable use of genetic resources into other management
- map and secure conservation of forest genetic resources, including through management plans

The Norwegian Environmental Agency and regional authorities for environment, are in charge of the forest protection measures in Norway, and for managing natural populations of forest trees in these areas, some of which have a dual purpose as gene conservation units.

The Norwegian Forest Seed Center is nationally responsible for providing forest tree seeds to forestry, breeding activities, establishment and maintenance of field trials, as well as procurement and storage of seeds for the forest sector. The national seed bank is located at the Forest Seed Center.

NIBIO is conducting valuable research for forestry, forest genetics, documentation and characterisation of forest genetic resources.

Table 14. Activities and cooperating partners in the Norwegian national programme on forest genetic resources.

Cooperative tasks/activities	Partner
***In-situ* conservation of FGR in natural populations, management included**	Norwegian Environmental Agency; regional authorities within forest and environmental management
***Ex-situ* conservation in collections**	NMBU; botanical gardens; arboreta; museums; Nordic Genetic Resource Center (SGSV), Norwegian Forest Seed Center
***Ex-situ* conservation in research and tree breeding**	NIBIO; NMBU; Norwegian Forest Seed Center; forest owners
Development of climatically adapted forest reproductive materials	NIBIO; Norwegian Forest Seed Center; NMBU; arboreta and botanical gardens; forest nurseries and forest plant societies
Monitoring of rare and threatened species and populations	NIBIO; universities; Norwegian Biodiversity Information Centre; Norwegian Institute for Nature Research
Documentation and databases	NIBIO; Norwegian Forest Seed Center; owners of collections; forest owners
Research in forest genetics and FGR	Norwegian Research Council; Norwegian Agricultural Agency; NIBIO; Norwegian Institute for Nature Research; universities
Teaching in forest genetics and FGR	NMBU; NIBIO
Business enterprise based on FGR	Norwegian Forest Seed Center; other R&D institutions; forest nurseries; economical organisations in forestry and private enterprises, forest owners
National legislation and legal questions related to FGR, import/export, including access and benefit sharing	Ministry of Agriculture and Food; Ministry of the Environment; Norwegian Environmental Agency; Norwegian Agricultural Agency; Committee for the Control of Forest Reproductive Materials; Norwegian Food Safety Authority; Fridtjof Nansen Institute
Information and public awareness	NIBIO, Cooperative R&D institutions and project partners, Nordic Genetic Resource Center (NordGen Forest)

11.2 Polices and strategies

A national strategy for conservation and sustainable use of genetic resources for food and agriculture was adopted by the minister of agriculture and food in December 2019. The strategy is a follow-up to Norway's national progress report on biodiversity for food and agriculture, which was Norway's contribution to the FAO Global Status Report of 2019. The strategy provides guidelines for continuation and developing the overall national work on genetic resources for food and agriculture, among others in accordance with the recommendations of the recently released UN reports.

Norway has several parallel processes and documents which jointly constitute the national forest programme. The most important elements are the Forestry Act (2005), the white paper on forest policy (2016), the annual national budget and the forest policy instruments.

PEFC is the dominating forest certification scheme in Norway. Norwegian PEFC forest certification is a complete certification system with rules for organization, forest standard with requirements for sustainable forestry, traceability, logo usage and control routines.

Forest genetic resources, and their conservation and use, are explicitly mentioned in several of the policy documents, both in general terms and in recommendations related to the production and use of forest reproductive material and in the implementation of important measures to mitigate climate change. Genetic resources are also specifically treated in the Nature Diversity Act adopted by the Parliament in 2009. This act regulates the conservation, access and use of genetic resources from nature, and also the import and release of alien organisms in Norwegian nature. Since 2014 an annual report on sustainable forestry has been published by NIBIO on behalf of the Ministry of Agriculture and Food. The report includes a chapter on forest genetic resources.

The Norwegian Ministry of Agriculture and Food is the national authority responsible for the Norwegian forest policy, which is based on a wide range of measures and instruments. These include legislation, tax policy, financial support schemes, research and guidance. Norwegian obligations through international agreements have also been incorporated into Norwegian regulations, including criteria for sustainable forestry negotiated in a European forestry cooperation. This is further elaborated in the following subchapter.

11.3 Legislation related to forest genetic resources

Main legislation relevant for conservation and use of forest genetic resources in Norway is the Forestry Act and the Nature Diversity Act. The purpose of the Forestry Act is to promote sustainable management of forest resources with a view to enhance active local and national economic development, and to secure biological diversity, consideration of the landscape, outdoor recreation and the cultural values associated with forest. The Forestry Act applies to all forest regardless of ownership.

The regulation of forest seeds and plants (from 1996), pursuant to the Forestry Act, aims to assure that reproductive material of high quality and adapted to planting site is being used in regeneration and that a high level of genetic diversity is maintained in the forest. A revision of the regulation is ongoing, to ensure that updated knowledge is incorporated.

A phytosanitary regulation aims to prevent introduction of pests and diseases and assures a healthy reproductive material. A revision of the existing phytosanitary regulation in Norway is underway. International trade of forest reproductive material is regulated by the OECD Forest Seed and Plant Scheme.

The Nature Diversity Act of 2009 contains provisions on forest protection and on prioritized species and selected habitats in forests that are important for specific groups of species. Voluntary protection, based on compensation to the forest owner, is now the main strategy for forest protection.

The Act further states that genetic material obtained from the natural environment is a common resource belonging to Norwegian society and managed by the state. Collection of genetic material from nature for use and further breeding or cultivation in forestry does not require a permit. The import for utilisation in Norway of genetic material from a state that requires consent for collection or export of such material may only take place in accordance with such consent.

A regulation under the Nature Diversity Act (Regulation on foreign tree species, from 2013) regulates planting of non-native tree species for forestry purposes. A permit is required from the local environmental authority before establishing plantations based on forest reproductive materials of non-native tree species. An additional regulation (Regulation on alien organisms, from 2015) regulates the import, circulation and release of alien species, as well as the accidental spread of these. Non-native tree species for forestry purposes are exempt from that regulation, but other uses of forest trees, for instance for horticultural purposes might be regulated.

Norway adheres to the 1978 Act of the UPOV Convention and the European Patent Organisation (EPO). However, at present there are no known cases of plant variety protection being applied for in the forestry sector, nor are there any patents so far. It is foreseen that such protection may be relevant in four cases: Christmas tree production, breeding new trees for biofuel production, plantations of tree varieties to capture and store carbon and breeding tree varieties for making them more tolerant to climate change conditions.

11.4 State of research and development

The major part of the research on forest genetic resources is performed by the Department of Forest genetics and biodiversity at NIBIO. Some research projects are also performed at the universities. The projects are financed by research grants given by the Norwegian Research Council, the Norwegian Agricultural Agency, the Nordic Council of Ministers and the European Union or by the institution's own budget. In NIBIO, the budget for forest genetics research amounts approximately NOK 6 million (2019), which is around 8,5 % of the total budget for forest research at the institute.

Information about the genetic units tested in research and breeding trials and records of traits measured, are kept in databases at the institutions that established these trials. A common database of all genetic units available in research and tree breeding is being developed as a joint project between The Norwegian Forest Seed Center and NIBIO. Documentation and discussion of the genetic knowledge obtained in research is presented in articles and reports published both in international and national journals.

Some of the research projects and activities that have provided valuable information for the breeding program and for gene conservation activities will be presented below. Further information about research topics are given in Chapters 5, 9 and 12.

To ensure sustainable breeding of *Picea abies* with sufficient genetic variation in bred material, a three-year research project "SustBreed: Approaching advanced-generation breeding in Norway spruce: balancing genetic gain and genetic diversity" was completed in 2018. Genetic diversity in seed lots from two seed orchards with different number of clones was compared with seed lots from forest stands. A small reduction in diversity was only found in the seed lots from the orchard with the lowest number of parents, less than 25. There is low differentiation between seed lots from forest stands and seed orchards. A pollen contamination from surrounding forests contributes to the genetic variability in the seed orchard. Between 30 and 60 unrelated parental clones are recommended for each seed orchard. In the breeding, a balanced selection of trees from many families contributes to keep a high diversity in the breeding population.

The national project "WoodRes: Breeding Norway spruce for beneficial wood properties and resistance against root rot and bark beetle associated blue-stain fungi attacks", have provided knowledge on resistance against the fungi in seedlings and saplings, but techniques for successfully breeding against them has not yet been developed. Most likely, molecular markers characterizing resistance genes will be needed.

Adaptation to the climate, both under current and climate change conditions, is an important factor in management of forest reproductive materials in the boreal forest. Therefore, studies are made both in the EU project B4EST ("Adaptive BREEDING for productive, sustainable and resilient FORESTs under climate change) and the Nordic project "Future Forests" with the aim to characterize reaction norms and their relationships to phenology traits and to model FRM performance under a wide range of climatic and biotic scenarios. Valuable information both for the breeding and for the deployment of materials will be provided from these studies.

The epigenetic response of seedlings of *Picea abies* to the temperature conditions during seed maturation has been studied in several projects. Initially, studies were made on quantitative traits related to adaptation and growth and more recently molecular genetic methods have been used. The research on epigenetic effects of adaptive traits in this species has high priority.

For conservation purposes, studies have been conducted recently for *Malus sylvestris* and *Fraxinus excelsior*. NIBIO has studied the genetic resources of *Malus sylvestris* (crab apple) in Norway since 2008, including threats of hybridization with *Malus domestica* and threats induced by habitat changes. Based on the results, crab apple was upgraded on the Norwegian Red List for species, from safe in 2010 to vulnerable in 2015. Conservation measures has been put in place, and a gene conservation unit has been established in the south of Norway.

A series of studies have been conducted to gain knowledge on the ash dieback disease (*Hymenoscyphus fraxineus*) which is affecting *Fraxinus excelsior* (Common ash) severely in Norway. The studies include monitoring the spread of the disease, knowledge related to management advise and studies of genetic variation, including possible resistance traits. A research trial of ash has recently been planted, with the aim to look for resistance.

11.5 State of education and training

Advanced education in topics related to agriculture and forestry at university level is the responsibility of NMBU. Their courses include basic genetics, population and quantitative genetics, molecular genetics and plant breeding.

Figure 21. Photo: Lars Sandved Dalen/NIBIO

Forest genetics and tree breeding is included as part of the basic course in silviculture and in the general course at the master level. No standalone university courses are offered in forest genetics or management of forest genetic resources. Therefore, foresters and managers of natural resources may not be familiar with the values of the conservation and sustainable use of forest genetic resources. Such courses are therefore needed.

No national course is offered in forest genetics or forest genetic resources at the doctorate level. However, PhD students in this field could follow courses offered in plant breeding and conservation of plant genetic resources. At the Nordic level, a doctorate course in plant breeding, where forest tree breeding is included, is offered regularly.

Forest tree breeding and the importance of choosing proper forest reproductive materials is regularly highlighted at regional and national meetings for nursery managers, the regional forest extension service and forest owners with contributors from NIBIO and the Norwegian Forest Seed Center.

11.6 Needs, challenges and opportunities for strengthening institutions and policies

Since the advisory committee of forest genetic resources no longer exists, some of the challenges ahead is to secure a resilient genetic resources programme through dialogue with relevant partners and to ensure dissemination of information to all target groups.

Cooperation between agriculture and environmental authorities should be further developed, for holistic management and conservation of FGR.

For most of the national tree species genetic information is scarce and the generation of better information and research should have high priority. This is in particular important in view of the changing climate conditions, both for the development of adapted reproductive material for the commercial species and for the management of forest tree genetic resources in general. Monitoring of the development of changes in genetic diversity to be able to actuate specific conservation activities when needed, is another challenge. This is in particular important for rare forest trees species and for their conservation *in situ*, which requires sustainable management in nature reserves, or specific *ex situ* conservation actions.

Phytosanitary regulations need to be effective to prevent the introduction and spread of forest pests and pathogens via transport and trade. Awareness should be raised among professionals, forest owners and policy makers. Existing phytosanitary regulations should be continuously updated with science-based knowledge. The use of physical control schemes of imported plant material should be given more weight. The effects of pests and diseases on forest genetic resources should be monitored and relevant actions to prevent spreading should be taken as soon as possible.

A challenge is to ensure that knowledge generated from research is properly communicated and taken into account when laws and regulations are decided, and that both such knowledge and practical experience are used in the management of the genetic resources.

11.7 Priorities for capacity building in this area

There is a cooperation between researchers in NIBIO and the educational courses at NMBU, to make sure that the most updated knowledge of FGR is communicated to the forestry students. Further cooperation between university courses in both nature management and forestry and the Norwegian

Genetic Resources Centre in NIBIO could be developed, for better communication on holistic management of FGR.

There is a need to further priorities funding of PhD students and researchers in the field of forest genetics.

The national FGR programme emphasizes further dissemination of data about forest genetic resources and information about the importance of their conservation and sustainable use through articles on websites and in social media, seminars and specific meetings and production of reports for a broad audience.

Figure 22. Norwegian forests seen from above, by drone. Photo: Ragnar Våga Pedersen/NIBIO

12 International and regional cooperation on forest genetic resources

12.1 International and regional activities

Norway supports regional and international agreements and cooperative programs on forest genetic resources and has played an active role in multilateral bodies and different actions. Regionally, cooperation has been at the Nordic and Baltic level, and internationally both at the European and global level.

12.1.1 Nordic cooperation

Nordic collaboration on research, conservation and use of forest genetic resources is an important component of the cooperation organized and financed by the Nordic Council of Ministers and its research body the Nordic Forest Research Co-operation Committee (SNS). From the start in 1972, Norwegian scientists have initiated and been partners in research and breeding projects in forest genetics and tree breeding.

The Nordic Council for Forest Reproductive Material, established in 1970, organised cooperative activities to increase the availability of suitable forest reproductive material and to promote successful forest regeneration in the Nordic countries. In 2008, this body was merged with the Nordic Gene Bank for agricultural plants and the Nordic Gene Bank Farm Animals to form the Nordic Genetic Resource Center (NordGen) with the aim to strengthen and coordinate genetic resource activities in the agricultural sector in the Nordic countries.

The forest sector of NordGen, NordGen Forest, is organised as a project lead by NIBIO, and receives additional economic support from Norway. It serves as a Nordic forum 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 by organising thematic days, conferences, seminars and meetings. The NordGen Forest network contains two external bodies, the Regeneration Council and the Working Group on Genetic Resources, each with members from all Nordic countries. Information and news related to forestry activities are presented on the web page of NordGen[10] and in publications.

The NordGen Forest Regeneration 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 NordGen Forest Working Group on Genetic Resources ensures co-operation in conservation and use of genetic resources of forest trees among the Nordic countries. It forms an interface between conservation activities at the national and the European levels (EUFORGEN), and initiates and implements activities that can improve or guide the conservation and use of forest genetic resources. In 2020, the Nordic cooperation published a status report on forest genetic resources conservation in the Nordic region.

In 2016, NordGen Forest conducted a survey among the major actors in the forest sector in Denmark, Finland, Norway and Sweden about their awareness of climate change. The report "Is Nordic forestry

[10] www.nordgen.org

prepared for climate change?" confirms that raising awareness about climate change is one of the main challenges for the Nordic co-operation on forests.

NordGen Forest has its 50 years anniversary in 2020.

12.1.2 European Networks

Norway has been a member of the European Forest Genetic Resources Programme (EUFORGEN) since its start in 1994. The programme aims at promoting conservation and sustainable use of forest genetic resources as well as serving as a platform for pan-European collaboration in this area, bringing together scientists, managers, policy-makers and other stakeholders.

EUFORGEN was originally structured in networks for species or groups of species, later thematic networks were added. In the last phases the mode of operation has been based on expert working groups and workshops to carry out specific tasks related to FGR in Europe. Norway has actively participated in most of these activities. The country has also contributed data on dynamic gene conservation units of forest trees in Norway to the European Information System on Forest Genetic Resources in Europe (EUFGIS), developed in close cooperation with EUFORGEN.

EUFORGEN was established as an implementing mechanism for the resolution conservation of forest genetic resources of the first Ministerial Conference on the Protection of Forests in Europe (FOREST EUROPE). Norway has continued to play an active role in FOREST EUROPE, through which the European ministers of forestry have committed themselves to conserve and enhance forest genetic resources as part of sustainable forest management.

NIBIO has recently been participating in three EU funded projects:

The EU funded management project GenRes Bridge (Genetic resources for a food-secure and forested Europe) aims to strengthen conservation and sustainable use of genetic resources by accelerating collaborative efforts and widening capacities in plant, forest and animal domains. The aim is to agree on a common European strategy for genetic resources overall. NIBIO is a partner in the project, which goes until 2021.

NIBIO has been actively involved in the project *Optimizing the management and sustainable use of forest genetic resources in Europe* (GenTree) during the period 2017-2020. The goal of this European research project was to provide the European forestry sector with better knowledge, methods and tools for optimising the management and sustainable use of forest genetic resources (FGR) in Europe, designing innovative strategies for dynamic conservation of FGR in European forests, broadening the range of FGR used by European breeding programmes and preparing new forest management scenarios and policy frameworks fully integrating genetic conservation and breeding aspects.

B4EST (Adaptive BREEDING for productive, sustainable and resilient FORESTs under climate change) is an EU-funded H2020 project which was established in 2018 and focuses on adaptive breeding for productive, sustainable and resilient forests under climate change. NIBIO is a partner in the project.

12.1.3 International programmes and agreements

Norway participates actively in the Commission of Genetic Resources for Food and Agriculture in FAO and in the national implementation of the FAO Global Plan for Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources. The country has been an active member of the FAO Intergovernmental Technical Working Group on Forest Genetic Resources since the start.

Norway takes an active part in research activities on forest genetic resources initiated by the International Union of Forest Research Organisations (IUFRO), and Norwegian scientists have established and maintained tests as part of the international provenance trials with Norway spruce and Western American conifers. In IUFRO, Norway recently chaired the Working Party Norway spruce genetic resources for two periods.

Norway has signed international agreements and takes part in international processes relevant to the sustainable use, development and conservation of forests. The United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) are of particular importance relative to forest genetic resources. The country has been an active force in the negotiations in United Nations Forum on Forests (UNFF) leading to a voluntary agreement at the global level for sustainable management of forests, and for reducing deforestation of the tropical forests.

12.2 Benefits and results from the international and regional cooperation

Being a small country with a limited number of actors involved in activities related to the conservation of forest genetic resources, Norway has benefited from both regional and international cooperation. At the Nordic level, both forest genetic research and development projects have dealt with species sharing more or less the same gene pool, and breeding is based on similar strategies, in particular for Norway spruce.

Establishing field trials with the same materials in several countries and common analyses of data from such experiments, have strengthened the generality of the results obtained. Some joint Nordic research projects have further developed into common projects at the European level that have generated new knowledge.

Information exchange and networking, development of technical guidelines and establishment of gene conservation strategies are activities that have been beneficial in the EUFORGEN collaboration.

12.3 Needs, challenges and opportunities

Continued cooperation between the Nordic and European countries through NordGen and EUFORGEN and in research is a great opportunity for solutions on common challenges. Norway is supporting ongoing work on an updated strategy for forest genetic resources in Europe through EUFORGEN.

The question on how to develop conservation strategies and make the conservation work as resilient as possible for the future, needs to be discussed at a national, but also Nordic and European level, for joint solutions. There is a question whether traditional *in situ* conservation efforts as stated in the Pan-European strategy are sufficient to secure the genetic resources against future challenges, including climate change, pests and diseases.

Raising awareness about climate change and the challenges and opportunities for forests is one of the main challenges for the Nordic co-operation. It is important that information is transferred to the forestry sector and that tools enabling science-based decisions are strengthened.

13 Recommended actions for the future

13.1 Availability of information on forest genetic resources

Generally, there is a lack of knowledge of the importance and implications of factors that may influence the genetic diversity of the forest tree species. To assure knowledge-based management of all forest genetic resources, documentation and characterisation should be strengthened.

Further studies should be made of genetic diversity in natural populations to provide information for gene conservation activities, particularly of adaptation to climate change and resistance against diseases.

13.2 Conservation of forest genetic resources

There is a need to aim conservation at more species and step up the establishment of *in situ* gene conservation units for forest genetic resources. This includes refining the climatic zoning and combining this with available knowledge of the genetic resources, to capture more of the genetic diversity and make conservation more effective.

In Norway gene conservation units have been included in already established nature conservation areas. There is a need for further strengthened cooperation with the environmental authorities and other partners, for *in situ* conservation of forest genetic resources to be considered as part of the main conservation goal for future protection areas and included in relevant formal regulations. There is an opportunity to take advantage of the ongoing voluntary forest protection scheme and increase the dialogue with environmental authorities and forest owners.

Valuable material in clonal archives and long term field trials related to breeding activities are important to conserve. The *ex situ* conservation scheme newly established for conservation of important breeding material should be further developed. Strategies for *ex situ* conservation of marginal species and genetic resources of species threatened by diseases should be developed.

There is a need to strengthen the links between conservation and use of forest genetic resources. For commercial species, conservation of genetic diversity is a prerequisite for current and future development of adapted forest reproductive material. For marginal species, there is a need to strengthen communication on conservation of genetic resources for potential use in an unknown future.

13.3 Use, development and management of forest genetic resources

There is a need to continue communication with forest owners and forest owners associations in order to assure their ability to choose appropriate forest reproductive material based on existing provenance recommendations.

Research related to breeding of forest reproductive material for conifers as well as broadleaves must be strengthened to assure sufficient and well adapted material for the future, taking climate change into account.

Further work is needed on deployment and transfer functions. Science-based decision support tools for the transfer of forest reproductive material should be further developed jointly in the Nordic countries.

Work should be undertaken to improve and strengthen a national system for traceability of forest material.

There is a need to further develop and offer well adapted reproductive materials of woody plant species for planting in the landscape, parks, along roadsides and in private gardens.

Existing phytosanitary regulations should be continuously updated with science-based knowledge. Awareness about precautionary measures should be raised among professionals, forest owners and policy makers. The effects of pests and diseases on forest genetic resources should be monitored and relevant actions to prevent spreading should be taken as soon as possible.

13.4 Policies, institutions and capacity building

Ensure a solid network of partners dedicated to the conservation and sustainable use of forest genetic resources through establishing cooperative partnerships, as well as meetings and seminars for capacity building on needs and challenges.

Continue work on communication on forest trees, the values and needs of forest genetic resources, and status of work.

Further develop Nordic and European cooperation in research, conservation and use in line with existing work in NordGen and EUFORGEN.

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Annex I:

2nd COUNTRY PROGRESS REPORT

NORWAY

Monitoring the implementation of the *Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources*

June 2020

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Part A: Responses of countries to the Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources

	Yes, No, Initiated, n.a.	Establishment, Year	Areas of work/activities/stakeholders
A.1.1.1 National FGR inventory	Y	2001	• Conservation of FGR • Production of forest reproductive material • Research and development efforts • FGR transferred internationally
Comments: The first national advisory committee for forest genetic resources was established in 2001. Since 2006, the Norwegian Genetic Resources Centre has taken this role.			
A.1.2.1 National FGR information systems	Y	2001	• Conservation of FGR • Production of forest reproductive material • Research and development efforts • FGR transferred internationally
Comments: The first national advisory committee for forest genetic resources was established in 2001. Since 2006, the Norwegian Genetic Resources Centre has taken this role.			
A.2.1.1 National *in situ* conservation system	Y	2001	• *In situ* conservation units of FGR • Protected areas
Comments: *The *in situ* conservation system for FGR is managed by the Norwegian Genetic Resources Centre, in cooperation with agricultural and environmental authorities.			
A.2.2.1 National *ex situ* conservation system	Y	2001	• Ex situ conservation stands • Storage facilities for seed, pollen or other tissue
Comments: Dedicated dynamic *ex situ* conservation stands in forest were established for valuable seed sources of Norway spruce (*Picea abies*) in 2018. Storage of seed at the Norwegian Forest Seed Center, with back-up storage at the Svalbard Global Seed Vault for some seed sources of *Picea abies* and *Pinus sylvestris.*			
A.3.1.1 National tree seed programmes	Y	1895	

Comments: The first national forest tree seed station (Hamar Klenganstalt) was established in 1895, changed name to Statens SkogfrÃ¸verk (Norwegian Tree Seed Station), and to Det norske SkogfrÃ¸verk (The Norwegian Forest Seed Center) in 1996.			
A.3.2.1 Tree breeding programmes	Y		• Private-public partnerships
Comments: The same organisation as stated above in qst 5.			
A.3.3.1 Extension programmes	Y	2001	Local communities Forest owners Others (please specify under Comments)
Comments: Activities on FGR directed to the general public, to education at different levels (schools, universities).			
A.4.1.1 National coordination mechanism	Y	2001	• Forest owners • Non-governmental organizations • Governmental organizations (including state-owned enterprises) • Research organizations (including universities) • Relevant ministries
Comments: Coordinated by the Advisory Committee for Forest Genetic Resources, and its successor, the Norwegian Genetic Resource Centre (established 2006).			
A.4.2.1 National FGR strategies	Y	2006	• Conservation of FGR • Use of FGR • Development of FGR
Comments: In 2006, the Advisory Committee for Forest Genetic Resources and thus the national programme for FGR was established. Its successor, the Norwegian Genetic Resource Centre was established in 2006. In December 2019, a national strategy for conservation and sustainable use of genetic resources for food and agriculture was adopted by the Norwegian minister of agriculture and food.			
A.4.3.1 Aligned with regional strategies	Y		
Comments: NordGen at the sub-regional level, EUFORGEN at the European level			
B.4.1.1 FGR integrated into NFP or national forest policies	Y		
Comments:			
B.4.1.2 FGR integrated into biodiversity action plans	Y		
Comments: "Link to the national biodiversity action plan: https://www.regjeringen.no/en/dokumenter/meld.-st.-14-20152016/id2468099/".			
B.4.1.3 FGR integrated into CC strategies	Y		
Comments: FGR use has been intergrated into a national adaptation strategy for climate change, but not FGR conservation.			
B.4.2.1 Participation in regional networks	Y		
Comments: Nordic Genetic Resource Center (NordGen) and EUFORGEN			
B.4.3.1 Participation in international R&D	Y	**Number of national organizations currently participating: 3**	
Comments: National organizations: NIBIO, The Norwegian Forest Seed Center and NMBU			

Part B: State of conservation, use and development of forest genetic resources

	National distribution available	Non-molecular characterization	Molecular characterization	*In situ* programme	No. of *in situ* units	Area of *in situ* (ha)	*Ex situ* programme	No. of *ex situ* units	Area of *ex situ* (ha)	No. of *ex situ* accessions	National tree seed programmes	Tree breeding programmes	Area of seed stands (ha)	No. of seed stands	Area of seed orchards (ha)	No. of seed orchards	Amount of planting stock produced per year	State of tree breeding programme
Acer platanoides	1	1	0	1	2	46.9	0				0	0						n.a.
Alnus glutinosa	1	1	0	0			0				1	1			1	2		1
Alnus incana	1	1	0	0			0				0	0						n.a.
Betula pendula	1	1	1	0			0				0	1	2.2	2				n.a.
Betula pubescens	1	0	0	0			0				0	0						n.a.
Corylus avellana	1	1	0	0			0				0	0						n.a.
Fagus sylvatica	1	0	1	1	2	46.5	0				0	0						n.a.
Fraxinus excelsior	1	0	1	1	3	74.2	0				0	0						n.a.
Ilex aquifolium	1	0	0	1	3	80.1	0				0	0						n.a.
Juniperus communis	1	0	0	0			0				0	0						n.a.
Malus sylvestris	1	0	1	0	1	29.2	0				0	0						n.a.
Picea abies	1	1	1	1	5	13189.3	1	8	49.5	197	1	1			109.7	17		2
Pinus sylvestris	1	1	0	0			1			11	1	1						n.a.

Populus tremula	1	0	0	0			0				0	0						n.a.
Prunus avium	1	0	0	0			0				0	0						n.a.
Prunus padus	1	0	0	0			0				0	0						n.a.
Quercus petraea	1	1	0	1	2	98.4	0				0	0						n.a.
Quercus robur	1	1	0	1	3	104.6	0				0	0						n.a.
Salix caprea	1	0	0	0			0				0	0						n.a.
Sorbus aucuparia	1	1	0	0			0				0	0						n.a.
Taxus baccata	1	0	1	1	3	118.4	0				0	0						n.a.
Tilia cordata	1	0	0	1	3	253.5	0				0	0						n.a.
Ulmus glabra	1	1	1	1	4	195.1	0				0	0						n.a.

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

NORWEGIAN GENETIC RESOURCE CENTRE
genressurser.no

NIBIO - Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossile economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.

NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own board.

The **Norwegian Genetic Resource Centre** has been established by the Ministry of Agriculture and Food, as a subsection at NIBIO.

The Norwegian Genetic Resource Centre coordinates expertise and activities regarding the conservation and utilisation of national genetic resources. The centre has been commissioned to contribute to the effective management of genetic resources in farm animals, crops and forest trees.

The centre also acts as an advisory body to the Norwegian Ministry of Agriculture and Food.

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