RAPPORT 2020/3

The second report on

The state of the world´s forest genetic resources

Sweden

SKOGSSTYRELSEN

AUTHORS
Sanna Black-Samuelsson
Andreas Eriksson
Jonas Bergqvist

FRONTPAGE
Daniel Hallin

Autumn colours in a deciduous forest in southern Sweden. Climate change and forest diseases increase the need to spread risks in forestry, for example by establishing mixed forests.

GRAFIC PRODUCTION
Bo Persson

UPPLAGA/EDITION
Finns endast som pdf-fil för egen utskrift
Only available as a PDF file

Contents

Preface

On behalf of the Swedish government, the Swedish Forest Agency publishes the second national report on the state of forest genetic resources in Sweden.

This report will together with other national reports form the basis for the second global report for forest genetic resources.

Sweden's landscape is dominated by forest, and the conservation and sustainable use of forest genetic resources is of vital importance for economical, ecological and social values. Our hope is that this report will lead to adequate measures in Sweden primarily concerning the management of forest genetic resources and necessary research and policy development.

We wish to express our gratitude to all who have contributed to this report.

Uppsala June 4, 2020

Herman Sundqvist

Director General,
Swedish Forest Agency

Sanna Black-Samuelsson

Associate professor forest genetics,
Swedish Forest Agency

Sammanfattning (in Swedish)

Denna rapport ger den hittills bredaste beskrivningen av skogsgenetiska resurser i Sverige. Rapporten presenterar status och åtgärdsbehov främst för användning, skötsel, institutionella ramverk, forskning, bevarande och information om skoggenetiska resurser i Sverige.

Status av skoggenetiska resurser

Sverige är ett skogsland. Skogen och skogsgenetiska resurser har ett stort värde för bland annat ekonomi, miljö, samhälle och biologisk mångfald. Av landets cirka 30 inhemska trädslag dominerar gran och tall med volymandelar på cirka 41 respektive 39 procent. Det finns åtskilliga hot mot skogen, främst viltskador, skadegörare och extrema väderhändelser. Flera av dessa hot förväntas tillta på grund av klimatförändringarna.

Kunskapen om skogsträdens genetiska variation är i allmänhet låg, även om forskning, utveckling och skogsträdsförädling av gran och tall är välutvecklad i flera aspekter, liksom det internationella forskningssamarbetet. Bevarandet av genetisk variation på växtplatsen (*in situ*) är funktionellt för vanliga inhemska trädslag, men inte för mindre trädslag med små och spridda populationer. Genbevarande utanför växtplatsen (*ex situ*) förekommer endast i liten utsträckning och det finns ingen genetisk övervakning av skogsträd. Medvetenheten om, lagstiftning, policyer, strategier och rådgivningstjänster för ett hållbart brukande av skogsgenetiska resurser är i allmänhet mycket begränsad.

Avverkning följt av föryngring med förädlat skogsodlingsmaterial av gran och tall är den mest dominerande skogsskötseln i Sveriges skogar. Värdet av metoder för att digitalisera olika aspekter av skogsbruk ökar successivt och Sverige är väl utvecklat i detta avseende.

Prioriterade åtgärdsbehov

Nedan listas, utan inbördes ordning, de mest prioriterade åtgärdsbehoven (i-v) som Skogsstyrelsen rekommenderar för skogsgenetiska resurser. Förslag på aktörer med störst ansvar för att hantera åtgärdsbehoven framgår av kursiv stil.

i) Öka medvetenheten om och synliggöra och integrera skogsgenetiska resurser mer systematiskt och tydligt i policyer, strategier och rådgivning som rör ett hållbart skogsbruk och bevarande av biologisk mångfald. *Ansvarig aktör: Skogsstyrelsen*

ii) Anpassa skogar för att bättre hantera klimatförändringar och ökade skogsskador och samtidigt främja den biologiska mångfalden genom att använda en ökad variation av trädslag (blandskog och lövskog), skogsbruksåtgärder (föryngring och skötsel) samt skogsodlingsmaterial. *Ansvarig aktör: skogsägare*

iii) Adressera forskning mer tydligt och systematiskt, främst konsekvenserna av användningen av skogsgenetiska resurser för produktions- och miljövärden, till regering, universitet och forskningsinstitutioner.
Ansvarig aktör: Skogsstyrelsen

iv) Utveckla ett nationellt system för att dokumentera vilket skogsodlingsmaterial som används i skogsbruket för att möjliggöra spårbarhet och analyser av relevans för produktions- och miljövärden, exempelvis samband mellan trädens genetik och skogsskador.
Ansvariga aktörer: Skogsstyrelsen, eventuellt i samverkan med relevanta universitet eller forskningsinstitutioner

v) Utveckla förädlingsprogram och fröproduktion för fler trädslag för att underlätta skogsägarnas val av skogsodlingsmaterial i ett förändrat klimat, samt arbeta mer aktivt i förädlingsprogrammen med resistens mot befintliga och nya problematiska skadegörare.
Ansvarig aktör: Skogforsk

Dessutom finns följande åtgärdsbehov (vi - x), angivna utan inbördes ordning:

vi) Klargöra hur gallring påverkar skogstillståndet och natur- och kulturmiljövärden, samt undersöka orsaker till skogens ekosystemtjänster med otillräcklig status och föreslå instrument och åtgärder som behövs för att förbättra den.
Ansvariga aktörer: Skogsstyrelsen och / eller relevanta universitet eller forskningsinstitutioner

vii) Öka uppmärksamheten på andra skogsmarker i forskning och övervakning utifrån dess betydelse för biologisk mångfald och begränsning av klimatförändringar.
Ansvariga aktörer: främst universitet och forskningsinstitutioner

viii) Säkra resurser för naturvårdande skötsel i biotopskyddsområden med och utan bevarade skogsgenetiska resurser.
Ansvarig aktör: regeringen

ix) Undersöka möjligheten att använda naturreservat för att bevara genetisk variation hos rödlistade skogsträd och trädslag med små och spridda populationer.
Ansvariga aktörer: relevanta myndigheter

x) Utveckla lämpliga metoder och system för genetisk övervakning av prioriterade skogsträd förutsatt att resurser tilldelas.
Ansvariga aktörer: universitet eller forskningsinstitutioner i samarbete med relevanta myndigheter

Åtgärdsbehoven är summerade i kapitel 13.

Summary

This report presents the statuses and action needs mainly concerning the use, management, institutional framework, research, conservation and information of forest genetic resources.

The statues of forest genetic resources in Sweden

Sweden's landscape is dominated by forest and forest genetic resources represent a significant national asset. These resources are of great value for the economy, environment, society and biodiversity, among other aspects.

Sweden has about 30 native tree species and the volume shares of the two dominating ones, *Picea abies* and *Pinus sylvestris*, are 41.0 and 39.1 percent, respectively. There are several biotic and abiotic threats to forests, mainly game damage, outbreaks of forest pests and severe weather events. Many of these threats are expected to increase due to climate change.

The knowledge of genetic diversity of trees is generally low, although research, development and forest tree breeding of *Picea abies* and *Pinus sylvestris* is well-developed in several aspects, as is the international (research) cooperation. The *in situ* conservation is functional for common native tree species, but not for tree species with small and scattered populations. There is hardly any *ex situ* conservation and no genetic monitoring of forest trees.

The awareness, regulations, policies, strategies and advisory services specifically concerning sustainable use of forest genetic resource is in general very limited.

Clearcutting followed by regeneration with genetically improved seedlings of *Picea abies* and *Pinus sylvestris* is the most dominating management practice in Sweden's forests. The value of digitalization methods for various aspects of forestry is constantly increasing and Sweden is highly developed in this regard.

Prioritized action needs

The most prioritized actions (i-v) that are recommended concerning forest genetic resources in Sweden are listed below, not in any particular order. The stakeholder(s) that are suggested as primarily responsible for dealing with the action needs are presented in italics.

i. Raise the awareness and more systematically address and integrate forest genetic resources in future policies, strategies and extension activities concerning sustainable forest management and biodiversity conservation. *Responsible actor: the national authority in charge of forest-related issues, i.e. the Swedish Forest Agency*

ii. Adapt forests to better cope with predicted climate change and increased forest damage, and simultaneously promote biodiversity, by an increased variation in tree species (mixed and deciduous forests), silvicultural measures (regeneration and management systems) and forest reproductive material. *Responsible actor: forest owners*

iii. Adress research needs more clearly and systematically, primarily concerning the use and management of forest genetic resources, to the government, universities and research institutions.
Responsible actor: the Swedish Forest Agency

iv. Develop a reliable national system that documents the forest reproductive material used in forestry, to enable tracing of information on and evaluations of various genetic aspects, such as forest damage, that can be of concern for both production and environmental values.
Responsible actors: the Swedish Forest Agency and/or relevant university or research institutions

v. Develop forest tree breeding programs and seed production for additional tree species to facilitate the choice of forest reproductive material in a changing climate and work more actively with the issue of resistance to existing and new problematic forest pests in the breeding programs.
Responsible actor: The Forest Research Institute of Sweden

Additional action needs

In addition, the following recommendations (vi – x) are suggested:

vi. To clarify how thinning affects the state of the forest, especially natural and cultural environmental values, as well as investigations on factors influencing the inadequate status of forest ecosystem services and the instruments and measures needed to improve their statues.
Responsible actor(s): The Swedish Forest Agency and/or relevant universities or research institutions

vii. Increase the attention to other wooded land in research and monitoring due to its importance for biodiversity and climate change mitigation.
Responsible actors: mainly universities and research institutions

viii. Secure resources for nature conservation management in the habitat protected areas that house gene conservation units in Sweden.
Responsible actor: the Swedish Government

ix. Investigate the potential to use nature reserves for gene conservation of red listed forest trees and tree species with small and scattered populations.
Responsible actors: relevant authorities

x. Develop appropriate methods and systems for the genetic monitoring of prioritized forest trees, provided that more resources are allocated
Responsible actors: universities or research institutions in collaboration with relevant authorities

The action needs are summarized in Chapter 13.

Introduction

The first report on The State of the World's Forest Genetic Resources was published in 2014[1]. It was an important milestone to create awareness and inform about recommendations to enhance the conservation and sustainable use of forest genetic resources at national and international levels.

In 2013, the FAO Conference adopted the global plan of action for forest genetic resources[2]. It identifies four priority areas for action concerning forest genetic resources (Table 1):

i) Improving the availability of and access to information;

ii) *In situ* and *ex situ* conservation;

iii) Sustainable use, development and management; and

iv) Policies, institutions and capacity-building.

The first global report was based, amongst other sources, on information provided from 86 countries. In the national report from Sweden[3], the need for *in situ* gene conservation of forest trees was highlighted as the most urgent aspect for development. As a consequence, the Swedish Forest Agency developed a strategy for gene conservation and since 2014, forest genetic resources are conserved in habitat protected areas. Evidently, the needs identified for action in a national report can accelerate development in priority areas.

This report covers the four priority areas of forest genetic resources mentioned above and is structured in six different parts (Table 1). The intention is not to present exhaustive knowledge in each area, neither is this requested from the FAO guidelines. The background description in each chapter is based on broad and comprehensive information from published reports and/or statistics and enables the identification of challenges, opportunities and priorities for research and capacity building.

FAO defines forest genetic resources as "*the heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific or societal value*". The interpretation is that all forest trees in Sweden should be considered as forest genetic resources as they all generate various benefits for the economy, environment, science or society.

---

[1] Commission on Genetic Resources for Food and Agriculture. 2014a. The State of the World's Forest Genetic Resources.

[2] Commission on Genetic Resources for Food and Agriculture. 2014b. Global plan of action for the conservation, sustainable use and development of forest genetic resources.

[3] Black-Samuelsson S. 2013. The state of the world´s forest genetic resources. Country report Sweden. In English with a Swedish abstract.

Table 1. Priority areas (i – iv), parts and heading of the chapters in the Swedish country report of forest genetic resources (FGR)

Priority area (i – iv) and part	**Content** (number of chapters in brackets)
Area i, part 1: The contributions of FGR to sustainable development	Value and importance of FGR (1)
Area i, part 2: State of diversity in forests and woodlands	The state of forests (2) The state of other wooded lands (3) Diversity between trees (4) Diversity within trees (5)
Area ii, part 3: State of conservation	*In situ* conservation (6) *Ex situ* conservation (7)
Area iii, part 4: State of use	Use of FGR (8) Genetic improvement and breeding programs (9) Management of FGR (10)
Area iv, part 5: State of capacities and polices	Institutional framework for FGR (11) International and regional cooperation on FGR (12)
Part 6: Challenges and opportunities	Recommended actions for the future (13)

In the foreword to the global plan of action, the closing message by FAO Director-General José Graziano da Silva was "*I call upon all countries to seize the opportunities provided by this global framework to strengthen the conservation and sustainable management of forest genetic resources and unlock its potential for the benefit of present and future generations*."

It is Sweden's ambition to seize these opportunities.

1 Value and importance of forest genetic resources

Part 1: The contributions of forest genetic resources to sustainable development

This chapter presents a narrative of Sweden and its economic, environmental, social and cultural conditions as they relate to forests and the forest sector. It also describes briefly the current and potential contributions of forest genetic resources to sustainable development.

1.1 Forests and forestry in Sweden

Sweden's landscape is dominated by forest. Approximately 28 million hectares (68 percent) of the land area of 40.8 million hectares is forested land. Of the forest area, more than 23,6 million hectares (about 84 percent) is productive forest land[4]. The land area described by traditional land use classes is given in Figure 1.

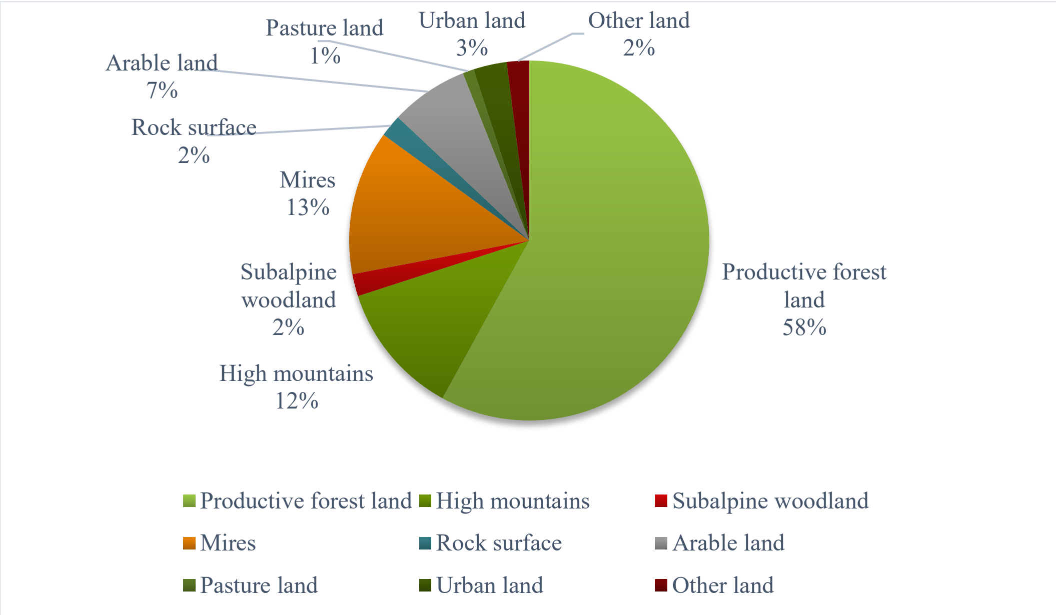

Figure 1. Land area in Sweden by traditional land use classes 2014-18. Source: Forest statistics 2019. Official Statistics of Sweden. Swedish University of Agricultural Sciences.

Sweden is divided into the regions Götaland, Svealand, Southern Norrland and Northern Norrland (Figure 2). Most of the country is covered by boreal forest which in its natural state contains a patchwork of habitats shaped by various disturbance regimes, notably forest fires, flooding and storms. Owing to the large latitudinal extent of the country (ranging from 55°N to 69°N), there is a considerable variation in climate and soil conditions, both of which are more favorable for tree growth in the south.

[4] Productive forest land is suitable for forest production and is not in any greater extent used for other purposes.

Eight vegetation zones can be distinguished in Sweden (Figure 2). The boreal zone and its sub-zones cover most of the land area and are dominated by coniferous forests, mainly *Picea abies* in the south and *Pinus sylvestris* in the north. In the south, there is a small zone, the nemoral zone, mainly with deciduous forests.

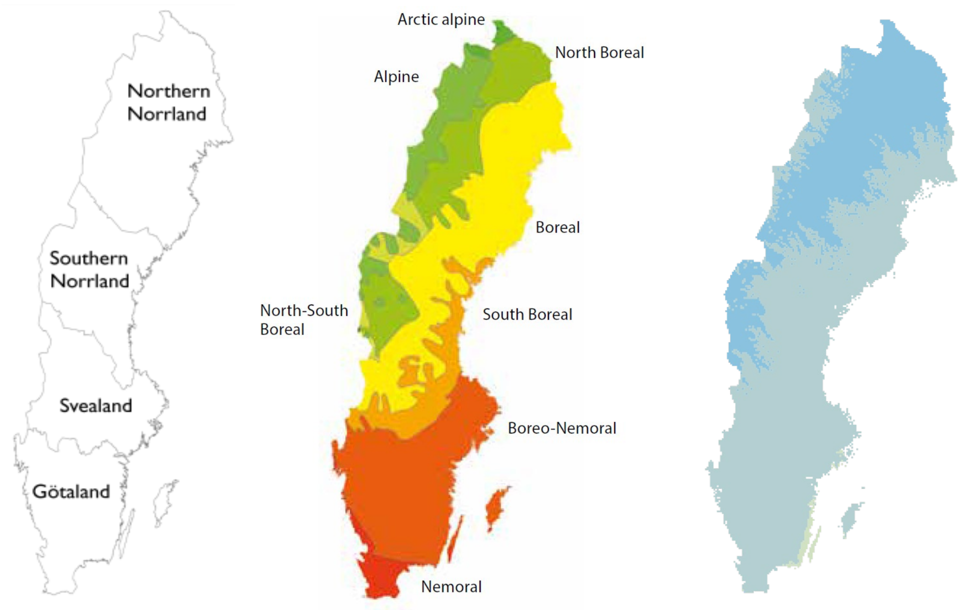

Figure 2. Three maps of Sweden. Left: Division of the country into the regions Götaland, Svealand, Southern and Northern Norrland. Middle: Eight vegetation zones. Right: Environmental zoning[5] used in a pan-European gene conservation strategy (section 6.1). Blue represent an extremely cold zone, turquoise is cold and moist (largest part of the country) and light green is cool and dry in small areas in south east.

1.2 Economic, environmental, social and cultural values

In economic terms forestry account for about one percent of the Swedish GDP and forest industry for another 1,5 percent[6]. Sweden however, a small country dependent on export, is one of the world's largest export nations in forest products, generating a surplus in the trade balance[7] (Figure 3). Almost 90 percent of the pulp and paper production is exported, and the export of sawn timber is close to 70 percent[8].

---

[5] The environmental zoning is based on Metzger MJ, Bunce RGH, Jongman RHG, Sayre R, Trabucco A & Zomer R. 2013. A high-resolution bioclimate map of the world: a unifying framework for global biodiversity research and monitoring. Global Ecology and Biogeography 22: 630–638.

[6] Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

[7] Statistics Sweden 2020. Foreign Trade – Exports and imports of goods January – December 2019. HA 22 SM 2001.

[8] Swedish forest industries. Forest industry significance. https://www.forestindustries.se/forest-industry/swedish-forest-industry/. Downloaded 2020-05-08.

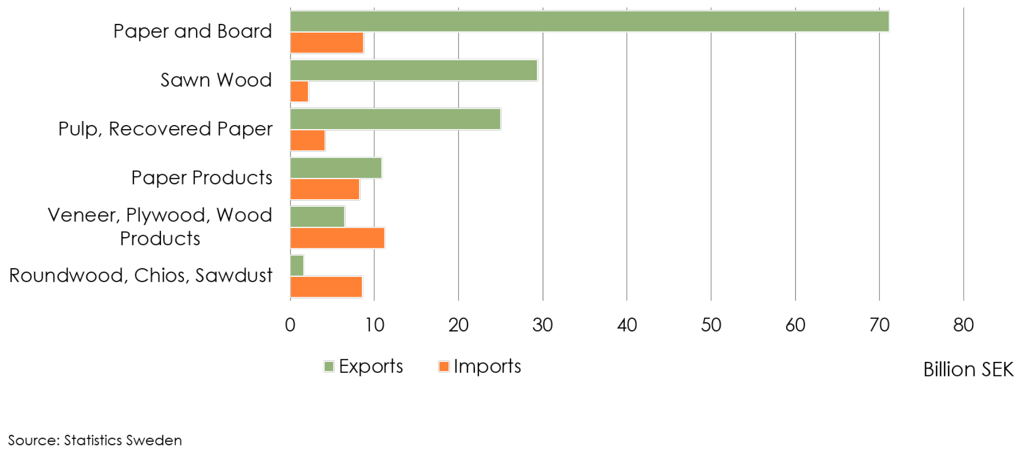

Figure 3. Exports and imports (in billion Swedish crownes, SEK) of forest industry products 2018. Source: The Swedish Forest Industries.

The net annual increment on forest land was 114 million m³o.b in 2015[9] (Figure 4). The mean annual felling during the same period was 91 million m³o.b. which gives a felling/net increment ratio of 80 percent. If the ratio where calculated on the annual volume increment on Forest Available for Wood Supply (FAWS), it would increase to around 91 percent[10].

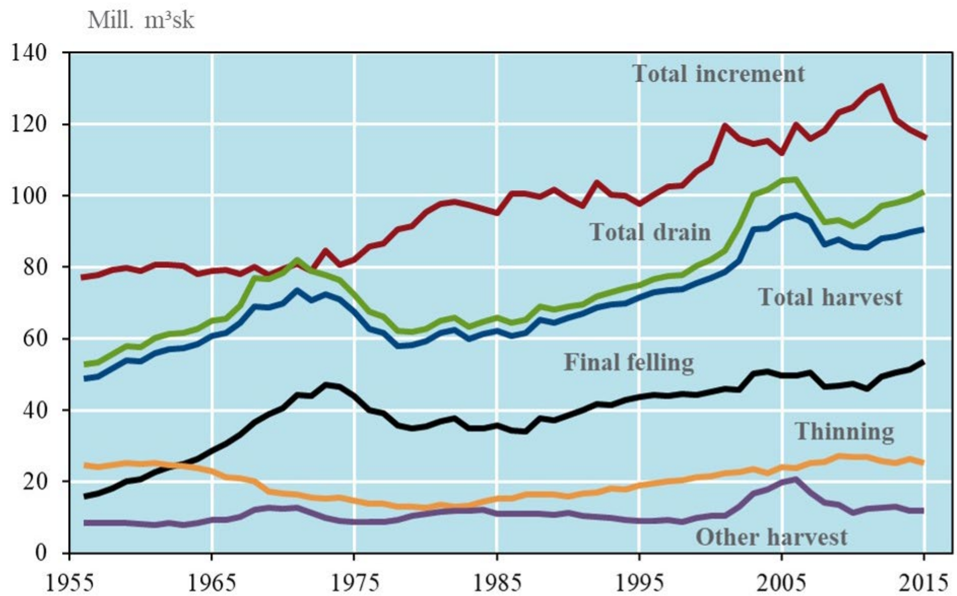

Figure 4. Annual total forest increment, total drain and total harvest (in million m³sk and calculated as five-year averages) between 1955 and 2015 in Sweden. Source: The Swedish National Forest Inventory, 2019.

---

[9] Forest statistics 2019. Official Statistics of Sweden. Swedish University of Agricultural Sciences.

[10] Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

Forestry and the forest industry are highly rationalized but still the number of people employed in forestry was around 22 000 in 2015. Another 29 000 where employed in manufacture of wood and wood products and another 26 000 in manufacture of paper and paper products[11].

Forests play a significant role for social and cultural values. For example, the Swedish forests are to a high extent owned by private individuals. About 319 000 individuals in 2017 owned in total 48 percent of the productive forest land[12]. Of them, 38 percent were women and 60 percent were men (gender data were missing for 2 percent). The number of management units owned by individual owners in 2017 was about 224 000 of which 67 percent were locally owned and 7 percent were partly owned by non-resident.

Forests are the single most visited natural environment besides built-up areas and one third of the population in Sweden visits a forest every week[13] (Figure 5). People who can roam freely in the forests generally acquire affection for nature and wildlife. The ancient "Right of Public Access" or "Freedom to roam" in Sweden is unique and gives the freedom to people for instance to camp and pursue outdoor recreational activities, pick berries and mushrooms regardless of forest ownership. Some prohibitions however include not to cut down trees or cause damage to a landowner's property or to objects or sites of natural, historical or heritage value.

1.3 Contribution to sustainable development

Genetic resources of forest trees are the hereditary material that has an actual or potential value for economy, environment, science and society[14]. Genetic resources contain functional units of heredity, such as seeds and plant parts[15] and include both economically important tree species utilized in forestry and naturally occurring species.

Forest genetic resources contributes to several sustainable development goals[16]. These are mainly to ensure access to affordable, reliable, sustainable and modern energy for all (goal 7); to ensure sustainable consumption and production patterns (goal 12); to take urgent action to combat climate change and its impacts (goal 13); and to protect, restore and promote sustainable use of terrestrial ecosystems,

---

[11] Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

[12] Christiansen L. 2018. Strukturstatistik. Statistik om skogsägande 2017. Skogsstyrelsen Rapport 2018/12. In Swedish with an English abstract.

[13] Naturvårdsverket 2019a. Uppföljning av målen för friluftspolitiken 2019. Rapport 6904. In Swedish.

[14] Food and Agricultural Organization of the United Nations. www.fao.org/forestry/fgr/en/. Downloaded 2020-05-08.

[15] Definition according to Regulation (EU) No 511/2014 of the European Parliament and of the Council of April 16, 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union.

[16] Andersson C, Blombäck P, Bondeson L, Celander T & Lundblad J. 2016. Agenda 2030 – underlag för genomförande. Skogsstyrelsen Meddelande 8, 2016. In Swedish.

sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (goal 15).

Forest management is essential for Sweden when it comes to achieving the goals of the Paris agreement and the national ambition to become the world's first fossil free welfare nation. In 2017, the net removal in the sector land use, land-use change and forestry (LULUCF) was estimated to circa 44 million tonnes CO_2-equivalent which is slightly more than the total CO_2-emissions[17].

The net removal in forest land increased from about 38 million tonnes to about 44 million tonnes of carbon dioxide equivalents between 1990 and 2017 mainly because the growth in forests and land has been larger than the harvests (footnote 17). Moreover, forest biomass could also be accounted for as substitution of fossil energy and carbon intensive materials. More than half of the energy used in Sweden comes from renewable energy sources, of which biofuels stand for a large part[18].

The priorities and needs in Sweden to enhance sustainable forest management and climate adaptation are described mainly in sections 10.3, 10.4 and 11.9.

Figure 5. Sweden is a landscape dominated by forests and forestry are of vital importance for the economy, environment, society and science. The ancient "Right of Public Access" in Sweden is unique and gives everyone the freedom to enjoy the forest. Photo: Jan Bengtsson, the Swedish Forest Agency.

[17] Naturvårdsverket 2019b. National Inventory Report Sweden 2019. Greenhouse Gas Emission Inventories 1990-2017 Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

[18] Statens Energimyndighet. 2019. Energiindikatorer 2019. Uppföljning av Sveriges Energipolitiska mål. Rapport ER 2019:11.

1.4 Constraints to increasing awareness on the value and importance of forest genetic resources

The Agenda 2030 goals that are related to forests and forestry issues are seldom discussed from the perspective of forest genetic resources. There is a general need of raising the awareness of forest genetic resources in the forest sector and among authorities and universities. This includes the perception that forest genetic resources encompass all tree species in Sweden, not only the major forestry species.

In most contexts the focus on biodiversity is on the ecosystem and species levels. This is somewhat surprising given that genetic variation is a prerequisite for species and forest ecosystems to adapt in a long-term perspective to biotic and abiotic environmental changes.

While aspects of conservation of biodiversity and the need of adaptation of forests and forestry to climate change remain important, the awareness of forest genetic resources and its importance for the Swedish forests and forestry obviously needs to increase. Forest genetic resources must be addressed more systematically and become properly integrated in future strategies for biodiversity conservation and sustainable forest management.

2 State of forests

Part 2: State of diversity in forests and woodlands

This chapter presents the state of forests in Sweden and explains briefly the trends that are shaping them. The focus is on the overall situation and its implications for forest genetic resources. The main drivers of change are identified and their challenges and opportunities for forest genetic resources are analysed.

2.1 State of Swedish forests

2.1.1 Land area and protected forests

Forests and forestry play a significant role in the Swedish society: economically, culturally and in shaping the landscape. The share of forest land has been very stable during the last century, however the standing volume has more than doubled since the first national forest survey in the 1920s[19]. The standing volume is today 3.5 million m^3o.b or on average 125 m^3o.b./ha.

Of the 28 million hectares of forest land 73 percent is classified as Forest Available for Wood Supply (FAWS)[20]. The remaining 27 percent is classified as Forest Not Available for Wood Supply (FNAWS) and are within formally protected forest land, voluntarily set-asides, consideration patches and unproductive forest land. The conservation work with formal protection of forests started in the beginning of the 20th century and has increased significantly since the 1970s[21]. Voluntary set-asides and retention patches in larger extent were introduced in Swedish forest policy in the 1990s.

According to recent official statistics[22], formally protected forest land covers a total of 2.3 million hectares in Sweden (Figure 6). Of these, almost 1.4 million hectares are productive forest land. 62 percent of the formally protected forest land is in the mountainous region, though they account for only 46% of protected productive forest land. Voluntary set-asides cover 1.2 million hectares or just over 5 percent of the productive forest land.

The statistics referred to above also show that almost 426,000 hectares of consideration areas have been accumulated during the period 1993 to 2018, corresponding to 1.8 percent of the productive forest land in the country. Most of the unproductive forest land is in the northern parts of Sweden. The three northernmost regions (mountainous, north boreal and southern boreal) have 88 percent of the unproductive forest land. In total, unproductive forest land comprises 16 percent of the total forest land area in Sweden.

[19] Forest statistics 2019. Official Statistics of Sweden. Swedish University of Agricultural Sciences.

[20] Statistics Sweden 2019. Formally protected forest land, voluntary set-asides, consideration patches and unproductive forest land. MI 41 SM 1902. Statistics Sweden. In Swedish with an English abstract.

[21] Statistics Sweden & Swedish Environmental Protection Agency 2019. Protected Nature 2018. MI 41 SM 1901.

[22] Skogsstyrelsen, Naturvårdsverket, Statistiska Centralbyrån & Sveriges Lantbruksuniversitet. 2019. Statistik om formellt skyddad skogsmark, frivilliga avsättningar, hänsynsytor samt improduktiv skogsmark. Skogsstyrelsen Rapport 2019/18. In Swedish.

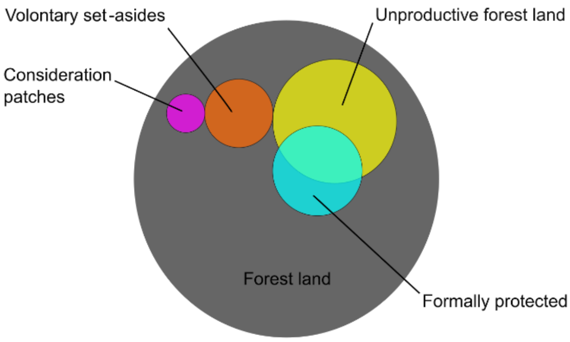

Figure 6. Graphics showing approximate areas (in million hectares) of different forms of forest land: formally protected forest land (2.3), voluntarily set-asides (1.2), consideration areas (0.43) and improductive forest land (outside and within forest protected land (3.2 and 0.9, respectively). The size of the circles correspond at large to the actual size of the land area. There is an overlap in the statistics between formally protected forest land and improductive forest land. Source: Skogsstyrelsen, Naturvårdsverket, Statistiska Centralbyrån & Sveriges Lantbruksuniversitet. 2019.

The responsible authorities for the formal protection of forest land, the Swedish Environmental Protection Agency and the Swedish Forest Agency, use a joint strategy. Given the focus of the strategy and current level of knowledge, genetic aspects have not been possible to consider within species conservation to any great extent. According to both authorities, this may pose a risk that genetically divergent populations of some species will not be able to be conserved in a long-term perspective[23].

2.1.2 Ecosystem services

In a report from 2018 the statues of 30 forest ecosystem services was assessed in Sweden[24] (Figure 7). The overall result revealed that the status of ten services including timber and pulpwood, air purification and pollination were categorized as good. Seven services including prevention of storm damage and erosion and biodiversity were identified as having an inadequate status. Thirteen services including water flow regulation and forest and nature for tourism were classified as having a moderate status (between good and insufficient in a three-grade scale).

The assessment mentioned above classified genetic resources as a supporting ecosystem service with a “moderate” status. It highlighted the dominance of a few tree species in the Swedish forests, the declining trend in using natural regeneration and the increasing trend of using *Picea abies* instead of *Pinus sylvestris* due to browsing problems. The lack of research and monitoring of forest genetic resources were also pointed out as problematic along with the spread of diseases on *Ulmus spp.* and *Fraxinus excelsior*.

---

[23] Naturvårdsverket och Skogsstyrelsen. 2017. Nationell strategi för formellt skydd av skog. Reviderad version 2017. In Swedish.

[24] Pettersson J, Andersson C, Ederlöf E & Fabricius Strömbäck A. 2018. Skogens ekosystemtjänster – status och påverkan. Swedish Forest Agency. Rapport 2017/13. In Swedish with an English abstract.

Figure 7. Four kinds of forest ecosystem services: provisioning services such as timber and pulpwood; regulating services such as prevention of storm damage; cultural services such as contributions to physical and mental well-being; and supporting services such as photosynthesis and genetic resources. Graphics: Bo Persson, the Swedish Forest Agency.

In the Swedish system of environmental quality objectives, genetic resources are part of the objective *Sustainable Forests* (section 11.3). The objective states that forest ecosystem services should be maintained and that there should be a diversity within and between populations of native species. The most recent evaluation of *Sustainable Forests*[25] uses the same assessment on genetic resources as an ecosystem service as mentioned above (footnote 24).

2.2 Forest biodiversity

The most recent evaluation of the Swedish environmental quality objective *Sustainable forests* states that the target hasn't been and will not be fulfilled by existing incentives and activities[26]. There are several positive trends both in activities to promote forest biodiversity and in the actual state of biodiversity. However, these activities are either not enough or have a time lag which means that there are still some negative trends regarding the state of forest biodiversity. Most highlighted are loss of valuable habitat, fragmentation and threatened species.

According to latest Swedish report on the Council Habitats Directive 92/43/EEC, most forest habitats are classified with unfavourable conservation status[27]. In the 2020 Swedish Red List[28], the number of red listed species and the number of threatened species (VU, EN or CR) increased compared to 2015, due to the assessment of a larger number of species and a higher share that were red listed.

[25] Andersson C, Andersson E, Blomqvist S, Eriksson A, Eriksson H, Karlsson S & Roberge J-M. 2019. Fördjupad utvärdering av Levande skogar 2019. Skogsstyrelsen Rapport 2019/2. In Swedish.

[26] Ibid.

[27] Swedish Species Information Center, Swedish University of Agricultural science 2019. The conservation status of the forest habitat types 9010-91F0 under the Habitats Directive 92/43/EEC in Sweden. SLU.dha.2019.5.2-16.

[28] Eide W *et al.* (red.) 2020. Tillstånd och trender för arter och deras livsmiljöer – rödlistade arter i Sverige 2020. SLU Artdatabanken rapporterar 24. SLU Artdatabanken, Uppsala. In Swedish with an English abstract.

The relationships between host tree species and their associated species across multiple organism groups have been assessed in Sweden[29]. Most native tree species turned out to be important to a large number of species. *Picea abies* had the highest number of host-dependent species (1,100), followed by *Pinus sylvestris* (920), *Quercus* (880), *Betula* (810), *Salix* (640), *Fagus sylvatica* (640) and *Populus tremula* (630). Approximately 50 % of the species associated with *Ulmus* and *Fraxinus*[30] are red-listed mainly because the host trees are also red-listed (section 4.4). The red-listed species tend to be concentrated to certain parts of their host plants' distributions.

2.3 Trends affecting forests and their management

As mentioned in section 2.1, the overall trend in Swedish forest policy and forest development during the last century is increasing standing volume, increasing removals and increasing area of Forest Not Available for Wood Supply (FNAWS). The Swedish forestry is also characterized by a high utilization of resources. In an international context, Sweden has one of the highest felling/net increment ratios on FAWS[31] (section 10.1). Forestry is also highly rationalized in planning, using new technology like LIDAR and drones, as well as in forest operations (section 10.2).

Regarding standing volume, the most common native forest tree species in Sweden are *Picea abies* (40.8 percent), *Pinus sylvestris* (39.3 percent) and *Betula spp.* (12.4 percent)[32]. *Pinus contorta* is the most commonly used introduced species (1.3 percent). The clearly dominating silvicultural system is standwise clearfelling. There is an increasing interest among forest owners in using management strategies with continuous forest cover, but those methods are uncommon.

During the last two decades the dominating trend in forest regeneration is the increased use of planting and the decreased use of natural regeneration (chapters 8 and 10) [33]. Recent data shows that planting is used on 84 percent of the regeneration area, natural regeneration on ten percent and seeding or no management on the remaining six percent[34].

Picea abies is still the most common species used for planting but there is an increasing trend last decade using *Pinus sylvestris* in planting. At the same time

[29] Sundberg S, Carlberg T, Sandström J. & Thor G. 2019. Värdväxters betydelse för andra organismer – med fokus på vedartade värdväxter. ArtDatabanken Rapporterar 22. ArtDatabanken SLU, Uppsala. In Swedish with an English abstract.

[30] Hultberg T, Sandström J, Felton A, Öhman K, Rönnberg J, Witzell J & Cleary M. 2020. Ash dieback risks an extinction cascade. Biological Conservation 244 (2020).

[31] UNECE/FAO. 2016. Pilot project on the System for the Evaluation of the Management of Forests (SEMAFOR). Geneva Timber and Forest Discussion Paper 66.

[32] Forest statistics 2019. Official statistics of Sweden. Swedish University of Agricultural Science. Umeå 2019.

[33] Black-Samuelsson S, Bergqvist J & Uggla C. 2017. Skogsträdens genetiska mångfald, status och åtgärdsbehov (Forest genetic resources – statues and measures needed). In Swedish with an English abstract. Swedish Forestry Agency. Report 2017/7.

[34] Svensson L. 2019. Quality of Regrowth 2018/2019. Statistical report JO0311 SM 1901. Swedish Forest Agency. In Swedish with an English abstract.

forest regeneration with the introduced species *Pinus contorta* is declining and there is a slight increased interest in using other introduced tree species such as *Larix x marschlinsii* and *Picea sitchensis*[35].

2.4 Drivers of change in the forest sector

The major driver for an active forest management is a high demand for wood, especially during the last couple of years[36]. A high global demand and a low rated Swedish currency have given extra speed to some of the trends mentioned in section 2.2. This could create opportunities for a profitable forestry and forest industry and future investments, but it also accentuates conflicts with biodiversity and other ecosystem services.

Climate change is high on the agenda for Swedish forestry, both in terms of adaptation and mitigation. Many problems during the last decades with wind throws, attacks by *Ips typographus* (European spruce bark beetle), wildfires and drought have highlighted the need for the forest sector to adapt to climate changes and create more resilient forests in terms of management practice (sections 4.3, 10.3-4). Simultaneously, there is a high demand for wood resources in order to substitute fossil-based materials.

The forest sector promotes progress towards sustainable forest management. For example, approximately 17.6 million hectares, or 63 percent of forest land, are under forest management certification schemes[37], including land owned by all major forest companies. These forest management standards regulate for instance the use of introduced forest tree species and in some cases also the use of native tree species[38,39] (section 11.5.4).

---

[35] Östberg K. 2020. Production of seedlings 2019. Statistical report JO0313 SM 2001. Swedish Forest Agency. In Swedish with an English abstract.

[36] Swedish Forest Agency 2019b. Market Statement 2019 – SWEDEN. UNECE Timber Committee Market Discussion 4-8 November 2019 Geneva, Switzerland.

[37] Statistics Sweden, Implementation of the 2030 Agenda in Sweden Statistical Review 2019.

[38] The FSC National Forest Stewardship Standard of Sweden. FSC-STD-003-05-2019 V-1

[39] Svenska PEFC ek för 2017. Svenska PEFC:s Skogsstandard. PEFC SWE 002:4.

The Swedish forest can play a significant role to ensure a sustainable society and a growing bioeconomy. For that reason, the Swedish Government adopted a strategy for Sweden's National Forest Programme and an action plan with specific measures[40]. The action plan will be updated in dialogue with interested parties. One of the five focus areas of the strategy is world-class innovations and refined forest raw materials where an increased industrial wood construction is included.

A long-lasting trend in Sweden is a more environmentally friendly society which in the forestry sector means progress towards sustainable forest management. A functioning green infrastructure is a prerequisite for sustainable forestry. Therefore, competent authorities and other actors in Sweden have prepared action plans for green infrastructure[41]. These plans provide a knowledge-based support concerning where in the landscape action is most beneficial and where special consideration is important. A varied use of the forest landscape can increase the forests resilience, reduce the risk of forest damage and favour biodiversity and several ecosystem services.

2.5 Challenges and opportunities

This report describes the challenges and opportunities concerning forest genetic resources for *in situ* conservation (section 6.3), *ex situ* conservation (section 7.2), use (section 8.5), genetic improvement (section 9.4), management (section 10.3), institutional framework (section 11.8) and cooperation (section 12.4).

The intensity in use of the Swedish forests leads to a situation where a large share of the forest area is managed yearly. With 255 000 hectares in clearing, 313 000 hectares in thinning and 187 000 hectares in clear-felling, three percent of the forest land is managed annually[42]. The way these operations are conducted has a big impact on the forest environment[43].

Previous assessments of the status of forest ecosystem services has revealed that the status for several services is inadequate (section 2.1.2). Therefore, there is a need to conduct in-depth analyses of ecosystem services that are deemed to have insufficient status. The purpose is to clarify the factors of influence and investigate which instruments and measures that are most suitable for improving the status of the ecosystem service. In a first step, a few ecosystem services could be selected and concurrently, broad socio-economic analyses should be conducted.

---

[40] Government Offices of Sweden. Fact sheet: Sweden's National Forest Programme. https://www.government.se/information-material/2019/01/fact-sheet-swedens-national-forest-programme/. Downloaded 2020-05-08.

[41] Naturvårdsverket. 2019c. Grön infrastruktur i skogen. Så kan du bidra. 2019. ISBN: 978-91-620-8833-0. In Swedish.

[42] Forest statistics 2019. Official statistics of Sweden. Swedish University of Agricultural Science. Umeå 2019.

[43] Felton A, Löfroth T, Angelstam P, Gustafsson L, Hjältén J, Felton AM, Simonsson P, Dahlberg A, Lindbladh M, Svensson J, Nilsson U, Lodin I, Hedwall PO, Sténs A, Lämås T, Brunet J, Kalén C, Kriström B, Gemmel P, Ranius T. 2019. Keeping pace with forestry: Multi-scale conservation in a changing production forest matrix. Ambio.

3 State of other wooded lands

This chapter very briefly presents the state of other wooded land and trees outside of forests in Sweden and the trends that are shaping them.

3.1 State of other wooded lands

Almost six percent of the land area in Sweden, 2.4 million hectares, is classified as other wooded land[44]. Most of this area is situated in northern Sweden, especially in alpine region. The growing stock in other wooded land is on average 7 m^3o.b./ha or in total 16.7 million m^3 o.b. of which two thirds is coniferous and one third is broadleaves[45].

Two dominating forest habitats are classified as other wooded land: Nordic subalpine/subartic forest with *Betula pubescens ssp. czerepanovii* and bog woodland. These types are considered as having a favourable conservation status (bog woodland in alpine and boreal region) according to latest report on the EU Habitats Directive[46].

3.2 Trends affecting other wooded lands and their management

The growing stock in other wooded land is increasing quite rapidly. In 2015, the growing stock was 20 percent higher than it was in 2005, and an estimation for 2020 is that this increase will continue and go faster[47]. 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.

3.3 Drivers of change in other wooded land

Other wooded land is not exploited by human activities. However, most likely a changing climate would affect these areas. In the alpine region the tree line is rising, and this will have an impact on the composition of trees and shrubs[48]. A changing climate could also affect bog woodland in shifting vegetation towards more shrubs and trees.

[44] Forest statistics 2019. Official statistics of Sweden. Swedish University of Agricultural Science. Umeå 2019.

[45] Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

[46] Swedish Species Information Center, Swedish University of Agricultural science 2019. The conservation status of the forest habitat types 9010-91F0 under the Habitats Directive 92/43/EEC in Sweden. SLU.dha.2019.5.2-16.

[47] Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

[48] Kullman L. 1998. Tree-Limits and Montane Forests in the Swedish Scandes: Sensitive Biomonitors of Climate Change and Variability. Ambio 27: 312–321.

3.4 Challenges and opportunities for the conservation, use and development of forest genetic resources

Other wooded land is not exploited in forestry or in other human activities in Sweden. Hence, they are also paid less interest regarding monitoring and research and therefore compared to forest land there is less knowledge about other wooded land. There is an interest in conducting nature conservation restoration on improductive forest land to generate values for biodiversity. More attention should therefore be payed to other wooded land in research and monitoring due to their importance for genetic resources, biodiversity and mitigation to climate change.

4 State of diversity of forest trees

This chapter provides information on the diversity of most native and introduced forest tree species that are considered as forest genetic resources in Sweden. Drivers of change in species diversity, including threats such as pests, diseases, game damage and consequences of climate change are also described.

4.1 Native forest tree species

Sweden has about 30 native forest tree species[49]. Mainly *Picea abies, Pinus sylvestris* and *Betula* are managed or utilized for forestry, with volume shares of 41.0, 39.1 and 12.1 percent, respectively (Table 2). Remaining native forest trees are to a limited extent used in forestry, with volume shares of less than two percent.

The growing stock for tree species on productive forest land and in all land classes[50] is given in Table 2. The shares of these tree species are in the same magnitude in productive forest land as in all land classes. The growing stock on productive forest land has increased for *Picea abies, Pinus sylvestris*, deciduous forests and *Pinus contorta* during the period 1955 to 2018 (Figure 8).

There is no agroforestry with native or introduced tree species in Sweden.

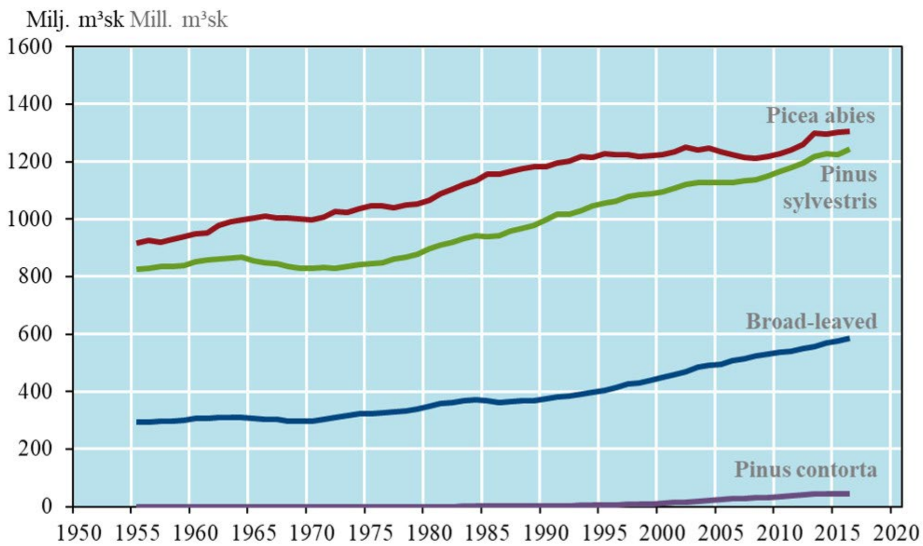

Figure 8. Standing volume by tree species (moving five year average, million m^{3}sk) during the period 1955 to 2016 on productive forest land in Sweden. The data exclude national parks, nature reserves and nature protection areas that are protected from forestry as of 2018. Source: The Swedish National Forest Inventory, 2019.

[49] *Acer campestre*, *Acer platanoides, Alnus glutinosa*, *Alnus incana*, *Betula pendula*, *Betula pubescens*, *Carpinus betulus*, *Coryllus avellana, Fagus sylvatica*, *Fraxinus excelsior*, *Juniperus communis*, *Larix sibirica*, *Picea abies*, *Pinus sylvestris*, *Populus tremula*, *Prunus avium*, *Prunus padus*, *Quercus petraea*, *Quercus robur*, *Salix caprea*, *Sorbus aucuparia*, *Sorbus intermedia*, *Taxus baccata*, *Tilia cordata*, *Tilia platyphyllos*, *Ulmus glabra*, *Ulmus laevis* and *Ulmus minor.*

[50] "All land classes" is the total land area in Sweden of 40.8 million hectares. This area includes productive forest land (69 percent), other wooded land (6 percent), bare, unproductive land (13 percent) and other land (12 percent). Definition from the Swedish National Forest Inventory.

Table 2. Estimated growing stock (share of species in %) of native tree species and introduced *Pinus contorta* in Sweden during 2014-18 in productive forest land[a] and in all land use classes[b] (data within brackets). Source: The Swedish National Forest Inventory, 2019.
a. Excluding national parks, nature reserves and nature protection areas that are protected from forestry activities as of 2018.
b. Excluding high mountains and urban forest land.

Tree species	Share (%) of productive forest land (all land classes)
Acer platanoides	0.1 (0.1)
Alnus (*glutinosa* and *incana*)	1.7 (1.7)
Betula (*pendula* and *pubescens*)	12.1 (12.5)
Fagus sylvatica	0.6 (0.6)
Fraxinus excelsior	0.1 (0.1)
Larix (*sibirica* and hybrids)	0.1 (0.1)
Picea abies	41.0 (40.4)
Pinus contorta (introduced)	1.4 (1.3)
Pinus sylvestris	39.1 (39.3)
Populus tremula	1.7 (1.7)
Prunus avium	1.7 (1.7)
Quercus (*petraea* and *robur*)	1.2 (1.3)
Salix caprea	0.5 (0.5)
Sorbus aucuparia	0.2 (0.2)
Ulmus (*glabra* and *minor*)	0.1 (0.1)

4.2 Introduced forest tree species

There are several introduced tree species in Sweden (Table 3). Besides *Pinus contorta*, primarily *Larix kaempferi*, *Picea sitchensis* and *Pseudotsuga menziesii* are used to a limited or marginal extent in forestry (Table 3). The use of most other introduced tree species is insignificant or non-existing in Sweden.

Table 3. Introduced tree species and artificial hybrids in the Swedish legislation (SKSFS 2002:2, Appendix 1). The estimated use in Swedish forestry is given in a falling scale: substantial, limited, marginal, none or insignificant. Other use means that the species is not used for forestry purposes

Tree species	Use in Swedish forestry
Abies alba Mill.	Marginal
Abies cephalonica Loudon	None or insignificant
Abies (D. Don) *grandis* Lindl.	Insignificant
Abies lasiocarpa (Hook.) Nutt.	Insignificant
Abies pinsapo Boiss.	None or insignificant
Acer pseudoplatanus L.	Marginal
Castanea sativa Mill.	Other use. Possibly naturalized
Cedrus atlantica (Endl.) Carrière	None or insignificant
Cedrus libani A. Rich.	None or insignificant
Fraxinus angustifolia Vahl., nom. cons.	Other use
Larix decidua Mill.	Marginal
Larix x marschlinsii Coaz	Limited
Larix kaempferi (Lamb.) Carrière	Marginal
Picea sitchensis (Bong.) Carrière	Limited
Pinus brutia Ten.	None or insignificant
Pinus canariensis C. Sm.	None or insignificant
Pinus cembra L. (including ssp. *sibirica*)	Other use. Possibly naturalized
Pinus contorta Loudon (including ssp. *contorta*, contortatall)	Substiantial (refers to *P. contorta* ssp. *latifolia*)
Pinus halepensis Mill.	None or insignificant
Pinus heldreichii H.Christ (including *leucodermis* Antoine)	None or insignificant
Pinus nigra (J.F.) Arnold	Marginal
Pinus pinaster Aiton	None or insignificant
Pinus pinea L	None or insignificant
Pinus radiata D. Don	None or insignificant
Populus spp. (except for *P. tremula*) and artificial hybrids between these species	Limited (refers to *P. tremula* x *tremuloides*)
Pseudotsuga menziesii Mirb. Franco	Marginal
Quercus cerris L.	None or insignificant
Quercus ilex L.	None or insignificant
Quercus pubescens Willd., nom. cons.	None or insignificant
Quercus rubra L.	None or insignificant
Quercus suber L.	None or insignificant
Robinia pseudoacacia L.	Other use

4.2.1 Invasive species

The Swedish Species Information Centre (SLU Artdatabanken) has estimated the potential risks from alien species on native biodiversity in Sweden[51]. Potentially harmful taxa within a future perspective of 50 years were screened and risk assessments were then performed on a selection of the species. The risk assessments were based on estimates of ecological effects and invasion potential from a fixed set of criteria based on the species' biology and distribution history. The method was used in combination with predictions of future climate.

The assessments resulted in classifying *Acer pseudoplatanus*, *Pinus contorta* and *Pinus mugo* subsp. *mugo* as "severe impact species", i.e. having the highest degree of invasivity. *Abies alba*, *Picea glauca* and *Populus alba* were classified as "high impact species" and *Picea sitchensis* was considered as having "potentially high impact".

The risk assessments also included several established forest pests in Sweden. *Hymenoscyphus fraxineus* causing ash dieback, *Ophiostoma novo-ulmi* causing Dutch elm disease and *Phytophthora alni* causing disease in *Alnus* spp. were classified as "severe impact species". *Ophiostoma ulmi* causing Dutch elm disease was classified as a "high impact species". *Phytophthora ramorum* causing disease in *Larix* (larch tree disease) and *Quercus* (sudden oak death) was considered as a "door knocker" (section 4.3.2).

4.3 Threats to forest tree species

There are several threats to production forests, mainly by game damage, outbreaks of insects and diseases, fires and severe weather events.

4.3.1 Game damage

Swedish forestry has for several decades faced severe problems with game browsing (Figure 9). The populations of moose, roe deer, red deer and fallow deer are very dense. As a result, *Picea abies*, being less desired by game, is used in regeneration instead of *Pinus sylvestris* in Southern Sweden even though the site conditions are not appropriate. This leads to secondary tree damage such as root rot or attacks by *Ips typographus*, the European spruce bark beetle. The consequences may be reduced tree growth, increased tree mortality, less resilience to climate change, decreased revenues and increased costs for forestry[52].

Browsing also cause problems for the regeneration of tree species such as *Sorbus, Populus tremula, Salix caprea* and *Quercus robur*, which appear as complementing seedlings in commercial forestry. Considering the large number of host dependent species on *Quercus*, *Salix* and *Populus* (section 2.2), biodiversity is also adversely affected by deer game damage.

---

[51] Strand M, Aronsson M & Svensson M. 2018. Klassificering av främmande arters effekter på biologisk mångfald i Sverige – ArtdDatabankens risklista. Artdatabanken Rapporterar 21. Artdatabanken SLU, Uppsala. ISSN: 1402-6090. In Swedish with an English abstract.

[52] Bergquist J, Kalén C & Karlsson S. 2019. Rapport 2019/16. Skogsbrukets kostnader för viltskador. Återrapportering till regeringen. Skogsstyrelsen. In Swedish.

Figure 9. A moose family looking for young *Pinus sylvestris* trees to eat. Swedish forestry has for several decades faced severe problem with game browsing. Photo: Kenneth Johansson, the Swedish Forest Agency.

The number of trees that are damaged by moose and the severity of the damages is surveyed annually[53]. The surveys are conducted in young forests with a tree height range of 1-4 meters. Also, assessments on food quantity for game are carried out in the forest. The results from the surveys are used for example to guide an appropriate number of moose to shoot each year.

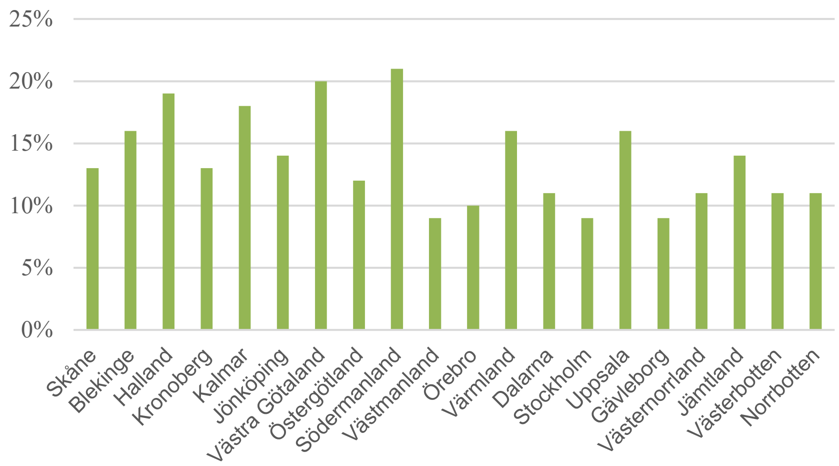

Figure 10. Share (%) of annually damaged young pines (1-4 meter high) by moose and other game in different regions of Sweden during 2017-18, moving from Southern Sweden (left) to the North. Ten percent or more of the surveyed trees are damaged in 17 out of 20 regions.

According to the above mentioned survey, the share of young *Pinus sylvestris* with fresh injuries since 2003 is in the range of 10-20 percent, reported as regional averages (Figure 10). This amount is substantially larger than the set goal of the forestry sector of maximum two percent annual damage by moose browsing. Besides damage on young *Pinus sylvestris* trees, many older trees of other species often sustain bark damage by moose and deer, especially red deer. However, there is no data on how common this type of damage is.

[53] Skogsstyrelsen. Äbin och andra skogliga betesinventeringar (Updated 2020-05-05). https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/abin-och-andra-skogliga-betesinventeringar/. Downloaded 2020-05-08.

4.3.2 Outbreaks of insects and pests

According to a new research study, the already large impacts on productivity and profitability in forestry and agricultural operations of 31 major insect pests are expected to become more serious as the global climate warms[54]. Several of the studied insects however exhibited mixed responses, with both a decrease and increase in severity according to geographical region and biological traits. Thus, the responses of insect pests to ongoing climate warming are not easy to generalize but need to be assessed individually.

Ips typographus causes severe problems for the Swedish forestry with *Picea abies*. Since 1995, the European spruce bark beetle is systematically monitored in parts of the country with pheromone traps and surveys of edge trees. The exceptionally dry and hot summer of 2018 in Sweden favored the beetle, as the trees were drought stressed and had a decreased defense capability. During 2018, three to four million cubic meters of growing forests were attacked and killed by the beetle in southern Sweden, corresponding to the largest estimated volume of *Picea abies* damaged by bark beetles during a single year. In 2019, this figure was doubled to seven million cubic meters[55]. The severity of the problem has led to extensive information and advice to forest owners both to prevent the outbreaks and to detect them at an early stage. Also, other bark beetles pose substantial threats to *Picea abies*, for instance *Polygraphus poligraphus.*

In northern Sweden, young trees of *Pinus sylvestris* are attacked by resin top disease *Cronartium flaccidum*. Together with other fungi and game, analysis of satellite images by the Swedish Forest Agency has shown that about one quarter of the 20 – 30 years old regenerations with *Pinus sylvestris* in the two northernmost provinces in Sweden have severe damages[56]. In 2016, there was a first large outbreak of a new disease, *Diplodia sapinea,* on *Pinus sylvestris*. This species has the potential to become a serious pathogen in Northern Europe [57].

Phytophtora alni has caused great damage to *Alnus* species in other countries and has been in Sweden for some time. Research on *Phytophthora* species obtained from nurseries, rivers, and forests has demonstrated that the species' distribution and community diversity are associated with climatic factors[58]. Milder winters will allow *Phytophtora alni* to spread north and *Alnus glutino*sa does not have any genetic resistance to this fungus. A decline of *Alnus* will likely result in erosion of shore face and affected nitrogen circulation.

---

[54] Lehmann P *et al*. 2020. Complex responses of global insect pests to climate warming. Front Ecol Environ 2020.

[55] Ståhlberg D, Eriksson H, Bergqvist J, Isacsson G & Lomander. 2020. Adaption of forests and forestry in Sweden to climate change: Objectives and proposals for action. Klimatanpassning av skogen och skogsbruket –mål och förslag på åtgärder. Skogsstyrelsen Rapport 2019/23. In Swedish with an English abstract.

[56] Normark E. 2019. Multiskadad ungskog i Västerbottens och Norrbottens län. Möjliga åtgärder för att mildra problemen. Skogsstyrelsen Rapport 2019/10. In Swedish with an English abstract.

[57] Brodde L *et al*. 2019. *Diplodia* tip blight on its way to the north: drivers of disease emergence in Northern Europe. Frontiers in plant sciences. doi: 10.3389/fpls.2018.01818.

[58] Redondo MA. 2018. Invasion biology of forest *Phytophthora* species in Sweden. Doctoral thesis Acta Universitatis Agriculturae Sueciae, 1652-6880. Sveriges lantbruksuniversitet 2018:22. Uppsala, Sweden. ISBN 978-91-7760-184-5. eISBN 978-91-7760-185-2.

4.3.3 Consequences of climate change

The RCP4.5 emission scenario, *i.e.* the scenario that best corresponds to the two degree goal, predicts a number of specific weather changes with relevance for Swedish forests and forestry (summarized and further analyzed by the Swedish Forest Agency)[59,60].

The annual average temperature will increase by approximately two degrees Celsius, more in northern Sweden than in the south and more during winter than in summer. The growing season will extend by 1–2 months and the precipitation will increase by 15–20 percent by next century. It will become more wet throughout the country during the winter and spring; however, the risk of drought will increase during summer in Götaland, Svealand and along parts of the Norrland coast.

Climate change is expected to have several consequences for the Swedish forests, including effects on biodiversity. This is, among other factors, connected to changed competition between species, darker forests and increased browsing pressure. Southern species will gradually migrate northwards. However, it takes long time for trees to establish and form mature forests which affect species that are dependent on these trees. Moreover, the value of the forests for outdoor life can be reduced due to increased damages caused by forest machines operating on moist soils.

The forest growth in Sweden, forest damages not included, is estimated to increase by approximately 25 percent by the end of the century. This implies that the wood quality will deteriorate in some respects and improve in others. Natural regeneration of more tree species will be favored. The risk that trees are felled by storms will increase (Figure 11) as a result of absence of frozen winter soils and higher groundwater levels during winter even if the wind speed will not change. If the share of *Picea abies* in forestry increases, it will also contribute to the risks. The risk of damage caused by the European spuce bark beetle will increase as a result of more storm felled trees and that drought stress will become more common in parts of Sweden (*cf.* 4.3.2). Without climate adaptation in forestry, the risk of European spruce bark beetle attacks will increase considerably during the second half of the century.

Another consequence of climate change is that the moose population is expected to decrease in southernmost Sweden, while other game is favored throughout the country. This is the result of the prolonged growth season. If no measures are taken, the browsing by cervids on young plants will likely increase. Then it will become even more difficult than today to spread risks in forestry by choosing different tree species.

[59] Eriksson H, Bergqvist J, Hazell P, Isacsson G, Lomander A & Black-Samuelsson S. 2016. Effekter av klimatförändringar på skogen och behov av anpassning i skogsbruket. Skogsstyrelsen Rapport 2, 2016. Skogsstyrelsen. In Swedish.

[60] Ståhlberg D, Eriksson H, Bergqvist J, Isacsson G & Lomander. 2020. Adaption of forests and forestry in Sweden to climate change: Objectives and proposals for action. Klimatanpassning av skogen och skogsbruket –mål och förslag på åtgärder. Skogsstyrelsen Rapport 2019/23. In Swedish with an English abstract

The large pine weevil, *Hylobius abietis,* and several other pests will be favored by climate change. Some new pests have already been introduced in Sweden and additional ones are to be expected[61]. The distribution of the basidiomycete fungi *Heterobasidion parviporum* and *H. annosum* will be favored by an increased harvesting during the growing season (Figure 11). These pathogens attack the roots, butts and stems of *Pica abies*. The affected trees decrease in growth over several years to decades before they eventually die.

When forest growth begins earlier during the year, the risk of damage caused by spring frost increases for conifers. In northern Norrland, snow-loads are likely to be more common while the risk of forest fire will increase in the south and east. With more mild and wet winters, the challenge of managing off-road driving and road transport without damaging land and watercourses increases. In addition, the risk of severe erosions is expected to increase.

Figure 11. Climate change pose several severe direct and indirect challenges to Swedish forestry. The risk that trees are felled by storm will increase (left). The fungus *Heterobasidion parviporum* and *H. annosum* is a serious pathogen in forestry and mainly attacks roots and stems of *Picea abies* (right). Photo: Michael Ekstrand (left) and Amanda Overmark (right), the Swedish Forest Agency.

4.4 Red-listed forest trees

The number of forest tree species is constant in Sweden. No tree species have gone extinct on a national scale during the past decades. According to the Red List from 2020[62], *Acer campestre, Tilia platyphyllos, Ulmus glabra* , *U. minor* and *U. laevis* are categorized as "Critically Endangered" and *Fraxinus excelsior* as "Endangered". These species have decreasing population numbers or sizes and may have gone locally or regionally extinct. There are no ongoing measures to protect these species, besides the gene conservation units that occur in habitat protection areas (Chapter 6).

[61] Karlsson L, Fries C, Granath-Limstrand P, Isacsson G, Rydberg D, Samuelsson H & Bertilsson A. 2012. Beredskap vid skador på skog. Skogsstyrelsen. Meddelande 3, 2012. In Swedish.

[62] SLU Artdatabanken. 2020. Rödlistade arter i Sverige 2020. SLU, Uppsala. In Swedish with an English summary.

Acer campestre occurs with one single wild population in southwestern Sweden[63]. It was discovered in 1749 and around 50 trees remain today. The species is widely regenerated and naturalized in many places in southern Sweden. Peat findings suggest that the species previously was more common in the Swedish flora. *Tilia platyphyllos* occurs in four minor (< ten trees) wild populations in southwestern Sweden[64]. Fossil pollen findings show a greater spread in western Sweden during postglacial time. *Ulmus laevis* occurs on a five-mile long area on the Baltic island of Öland in about 120 localities, usually with only a few trees[65]. It is regenerated in several places in southern Sweden and is naturalized in single localities.

Dutch elm disease in combination with ash dieback pose a serious threat to the Fennoscandian wooded meadows and old broad-leaved deciduous forests[66] listed in the Annex 1 of the Council Habitats Directive 92/43/EEC. *Ulmus* spp. and *Fraxinus excelsior* make up almost 70% of the old growth tree layer on the Island of Gotland. Between 2013 and 2018, extensive work within an EU Life ELMIA project on the Baltic island of Gotland identified and eradicated infected and risk trees, successfully keeping Dutch elm disease under control[67] (Figure 12). Also, measures for how to combat the disease were developed and improved.

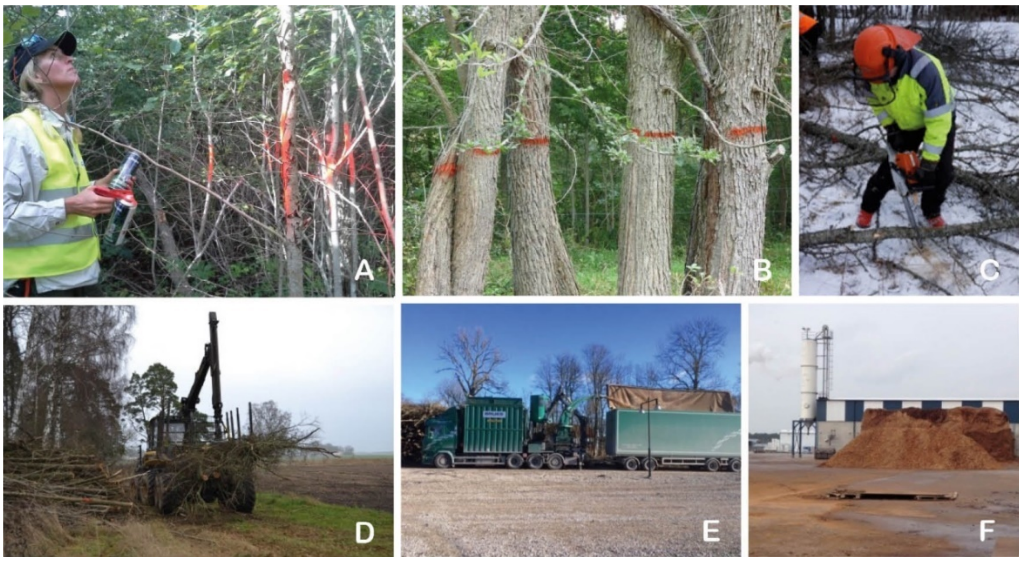

Figure 12. Dutch elm disease cause severe damage to *Ulmus* spp. and associated species in Sweden. However, on the Baltic island of Gotland, a control program of the disease has resulted in high (90 percent) survival of *Ulmus* spp. The program identifies and marks infected trees, also with GPS-coordinates (A, B). The trees are harvested (C) and transported away (D). Trees are splinted direct in a container (E) and are transported to heating plants for local district heating (F). Photo: Astrid Dale (A, B), Johan Malmberg (C, D), and Karin Wågström (E, F).

---

[63] Artfakta SLU Artdatabanken. Naverlönn *Acer campestre*. https://artfakta.se/artbestamning/taxon/5.Downloaded 2020-05-13.

[64] Artfakta SLU Artdatabanken. Sweden. Bohuslind *Tilia platyphyllos*. https://artfakta.se/artbestamning/taxon/1563. Downloaded 2020-05-13.

[65] Artfakta SLU Artdatabanken. Vresalm *Ulmus laevis*. https://artfakta.se/artbestamning/taxon/ulmus-laevis-1628. Downloaded 2020-05-13.

[66]Skogsstyrelsen Swedish Forest Agency. Life ELMIAS. https://skogsstyrelsen.se/en/lifeelmias/. Downloaded 2020-05-13.

[67] https://www.skogsstyrelsen.se/globalassets/projektwebbplatser/life-elmias/rapporter/lifeelmias-final-report.pdf. Downloaded 2020-05-13.

5 State of diversity within trees

This chapter provides information and trends concerning genetic diversity and the state of populations in terms of health and population numbers in forest genetic resources in Sweden.

5.1 General state of knowledge

A basic prerequisite for mapping and monitoring the genetic variation of forest trees is knowledge of their distribution. There is information on the geographical distribution in the Nordic region and in the northern hemisphere for trees and larger bushes[68]. The pan-European cooperation organization Euforgen has published distribution maps for several tree species in Europe[69]. In 2016, the European Commission published the first atlas of forest trees in Europe with information on tree species distribution, habitat, use and threats[70].

Genetic variation in natural populations and in forest regeneration is largely influenced by human activity. Several factors have an impact, mainly landscape fragmentation, forest damage (chapter 4) and the regeneration by planting with *Picea abies* and *Pinus sylvestris* (chapter 10).

There are few studies on previous and present amounts of genetic diversity in natural populations and cultivated stands of forest tree species. Therefore, it is difficult to discuss trends in genetic variation. Consequently, it is conceivable that genetic variation, both in numbers of alleles and levels of heterozygosity, is affected in several forest tree species.

Population numbers and sizes in *Ulmus glabra* and *Fraxinus excelsior* have decreased due to the serious infections of Dutch elm disease and ash dieback, respectively. Despite limited studies, genetic diversity is presumably lost at a high rate within and across populations in both tree species.

In *Picea abies* and *Pinus sylvestris*, quantitative genetic variation is assessed in selected traits in connection with analysis of the breeding programs.

5.2 Genetic variation and monitoring

Genetic monitoring of forest genetic resources is an important part of monitoring biodiversity. It provides information concerning the long-term ability of a forest stand to survive and adapt under rapid biotic and abiotic changes. The theoretical

[68] Naturhistoriska Riksmuseet. Den virtuella floran. http://linnaeus.nrm.se/flora/welcome.html. Downloaded 2020-05-13.

[69] EUFORGEN, European Forest Genetic Resources Programme. http://www.euforgen.org/. Downloaded 2020-05-13.

[70] European Atlas of Forest Tree Species, European commission 2016. On-line version. ISBN 978-92-79-52833-0. DOI 10.2788/038466. Catalogue number LB-04-14-282-EN-N.

concepts developed for genetic monitoring however need to be evaluated and optimized before they are implemented[71].

In Sweden, no scientific or technical approaches or mechanisms have been used to monitor genetic variation in forest trees in natural populations or in forestry[72]. The need for genetic monitoring of native animal and plant species in general has been recognized for some decades. It is also encompassed in Sweden's system for environmental objectives[73], including different types of goals. For instance, the generational goal[74] defines the overall direction of environmental efforts. To facilitate these efforts and to make the generational goal more tangible, there are 16 environmental quality objectives and a number of milestone targets.

One of the environmental quality objectives is "*A Rich Diversity of Plant and Animal Life*". One specification of this objective aims to ensure that "*Habitats and species that occur naturally in Sweden have a favorable conservation status, the status of threatened species has improved, and sufficient genetic variation is maintained within and between populations*."

The milestone targets are intended to identify a desired social change and specify steps towards achieving the generational goal and one or more of the environmental quality objectives. The milestone target regarding biodiversity has the following goal concerning knowledge about genetic diversity "*Mapping and monitoring of genetic diversity are to be initiated by 2020*."

For this reason, a mapping and monitoring program[75] targeting genetic diversity in several organism groups is currently discussed among relevant authorities and researchers in Sweden. A main goal of the program is to follow rates of genetic change in natural populations in order to detect changes in the diversity that may affect the long-term survival and fitness of the populations and species in question. The aim is to monitor genetic variation over time scales going back maximum 100 years from present and assess genetic changes.

---

[71] Fussi B, Westergren M, Aravanopoulos F, Baier R, Kavaliauskas D, Finzgar D, Alizoti P, Bozic G, Avramidou E, Konnert M & Kraigher H. 2016. Forest genetic monitoring: an overview of concepts and definitions. Environtal Monitoring and Assessment 88: 493.

[72] Black-Samuelsson S, Bergqvist J & Uggla C. 2017. Skogsträdens genetiska mångfald, status och åtgärdsbehov (Forest genetic resources – statues and measures needed). Skogsstyrelsen Rapport 2017/7. In Swedish with an English abstract.

[73] Swedish Environmental Protection Agency. The environmental objectives system. Updated 2019-08-15. http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-environmental-objectives-system/. Downloaded 2020-05-15.

[74] The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders.

[75] Posledovich D, Ekblom R & Laikre L. 2020. Mapping and monitoring genetic diversity in Sweden – suggestion for program to start 2020. Manuscript.

A central issue of genetic monitoring is to identify prioritized species. Different criteria for categorizing and prioritizing species for genetic monitoring programs have been proposed[76]. If forest trees in Sweden would be genetically monitored at a relevant and resource efficient scale, following categories of trees may be the most prioritized[77]:

i) Red-listed forest trees with rapidly decreasing population numbers and/or sizes, such as *Fraxinus excelsior* (Figure 13) and *Ulmus* spp.

ii) Forest trees where forestry has an impact on genetic diversity, for example *Picea abies* and *Pinus sylvestris*; and

iii) Forest trees occurring with their northern marginal populations in Sweden, such as *Prunus avium*, *Sorbus intermedia*, *Taxus baccata*, *Quercus petrea* and *Ulmus minor*. Populations of these tree species may be genetically distinct from conspecific populations originating from other parts of the distribution range[78].

Genetic monitoring of forest genetic resources is further discussed in sections 12.3 and 12.4.

Figure 13. Ash dieback cause severe damage to *Fraxinus exelsior* in Sweden, but genetic variation in clonal susceptibility to the disease give hope and enables tree breeding of healthy trees. Photo: Sanna Black-Samuelsson, the Swedish Forest Agency.

---

[76] Laikre L, Larsson LC, Palmé A, Charlier J, Josefsson M & Ryman N. 2008. Potentials for monitoring gene level biodiversity: using Sweden as an example. Biodiversity Conservation 17:893-910. doi 10.1007/s10531-008-9335-2.

[77] Black-Samuelsson S, Bergqvist J & Uggla C. 2017. Skogsträdens genetiska mångfald, status och åtgärdsbehov (Forest genetic resources – statues and measures needed). Skogsstyrelsen Rapport 2017/7. In Swedish with an English abstract.

[78] Fady B, Aravanopoulos FA, Alizoti P, Mátyás C, von Wühlisch G, Westergren M, Belletti P, Cvjetkovic B, Ducci F, Huber G, Kelleher CT, Khaldi A, Bou Dagher Kharrat M, Kraigher H, Kramer K, Mühlethaler U, Peric S, Perry A, Rousi M, Sbay H, Stojnic S, Tijardovic M, Tsvetkov I, Varela MC, Vendramin GG & Zlatanov T. 2016. Evolution-based approach needed for the conservation and silviculture of peripheral forest tree populations. Forest Ecology and Management 375: 66–75.

5.3 Examples of research on genetic variation

This section gives a few examples on technologies that are currently used or are emerging in Sweden for various genetic studies and assessments (Figure 14).

In 2013, a draft assembly was published of the 20-gigabase genome of *Picea abies*, the first one available for any gymnosperm[79]. The large genome size seems to be the result of a steady accumulation of different repeated transposable elements, long introns and long non-coding RNAs. The results on genome sequence and evolution are important for further breeding in *Picea abies*. Recently, an ultra-dense genetic map of *Picea abies* was published and it was concluded that the map was sufficiently dense to enable detailed evolutionary genomic analyses in this tree species[80].

Breeding populations of *Picea abies* in northern Sweden have been evaluated using nuclear microsatellite markers[81]. The results showed high genetic diversity, low population differentiation and unstructured relatedness between individuals in the breeding populations. The population differentiation pattern was concluded to be consistent with the post glacial migration history of *Picea abies* and the current gene flow and human activity in the region.

Genetic diversity, assessed with microsatellite markers in seeds of *Picea abies*, was revealed to be slightly lower (mainly in allelic richness) in two seed orchards of *Picea abies*, when compared with seed stands and natural stands[82]. Moreover, pollen contamination was important to maintain the genetic diversity, especially in seed lots derived from a few parents.

Mating structure and gene flow was analyzed in a clonal seed orchard of *Pinus sylvestris* over three consecutive pollination seasons with nuclear microsatellite markers[83]. The results indicated only minor negative effects of self-fertilization and pollen contamination in the seeds from the seed orchard.

---

[79] Nystedt B *et al*. 2013. The Norway spruce genome sequence and conifer genome evolution. Nature. May 30; 497:579-584. doi: 10.1038/nature12211.

[80] Bernhardsson C, Vidalis A, Wang X, Scofield DG, Schiffthaler B, Baison J, Street NR, García-Gil MR & Ingvarsson PK. 2019. An Ultra-Dense Haploid Genetic Map for Evaluating the Highly Fragmented Genome Assembly of Norway Spruce *(Picea abies*). G3: Genes, Genomes, Genetics 9:1623-1632.

[81] Androsiuk P, Shimono A, Westin J, Lindgren D, Fries A & Wang X-R. 2013. Genetic status of Norway spruce (*Picea abies*) breeding populations for northern Sweden. Silvae Genetica 62:127-136.

[82] Sønstebø JH, Tollefsrud MM, Myking T, Steffenrem A, Nilsen AE, Edvardsen ØM, Johnskås OR, El-Kassaby YA. 2018. Genetic diversity of Norway spruce (*Picea abies* (L.) Karst.) seed orchard crops: Effects of number of parents, seed year, and pollen contamination. Forest Ecology and Management 411: 132–141.

[83] Funda T, Wennström U, Almqvist C, Torimaru T, Andersson Gull B & Wang X-R. 2015. Low rates of pollen contamination in a Scots pine seed orchard in Sweden: the exception or the norm? Scandinavian Journal of Forest Research 30: 573-586.

Figure 14. At several universities in Sweden, advanced research is underway to study a variety of aspects of genetic variation in laboratories (left) and growth chambers (right) of forest trees, mainly in *Picea abies*, *Pinus sylvestris* and *Populus*. Photo: Julio Gonzales, SLU.

Umeå Plant Science Centre (UPSC) and the Science for Life Laboratory have started a comprehensive research collaboration on tree genes, forest biotechnology and forest genetics[84]. One aspect of the research is to identify new genes that control growth and wood formation in trees. Another is focusing on genomics and forest genetics and aims to develop a significantly improved version of the *Picea abies* genome. In parallel, the genome of *Pinus sylvestris* will be sequenced. The analyses also include the genomic variation of the trees that are linked to the Swedish breeding programs of *Picea abies* and *Pinus sylvestris*. One of the objectives is to provide basic research tools to understand the natural genetic variation in forest trees and to facilitate the development of genomic selection in forest tree breeding.

Genetic diversity is currently examined in three types of materials in *Pinus sylvestris* and *Picea abies*: range-wide natural populations, selected elite trees within breeding populations and trees from seed orchard crops[85]. Genetic variation in the Scandinavian populations will be compared with other populations across the species´ whole distribution range. The objectives are to understand the evolutionary history of these conifers in Scandinavia, and how much of the diversity that is captured in the breeding programs. This assessment will help to optimize current forest management for future challenges.

The tree species *Populus* provides a powerful study system to understand the genomic factors determining adaptive evolution. A full-genome sequence analysis of *Populus tremuloides* and *P. tremula* has revealed substantial levels of genetic variation[86]. The results showed that both positive and negative selection are important for shaping genome-wide levels of genetic variation.

---

[84] Umeå Plant Science Center. The Knut and Alice Wallenberg Foundation approved large projects on tree research. Updated 2019-01-14. https://www.upsc.se/about-upsc/news/5457-the-knut-and-alice-wallenberg-foundation-funds-a-large-project-on-spruce-and-pine-research.html Downloaded 2020-05-15.

[85] Umeå University. The status of genetic diversity in Swedish conifer forests: are there reasons for concern? https://www.umu.se/en/research/projects/the-status-of-genetic-diversity-in-swedish-conifer-forests-are-there-reasons-for-concern-/ Downloaded 2020-05-08.

[86] Lin Y-C *et al.* 2018. Functional and evolutionary genomic inferences in *Populus* through genome and population sequencing of American and European aspen. PNAS vol. 115 (46).

The genomic basis of local adaptation in the initiation of growth cessation and dormancy has been investigated in natural populations of *Populus tremula* over a large geographical scale[87]. The timing of bud set was explained by a major locus effect that facilitated rapid adaptation to shorter growing seasons and colder climates.

Although most molecular forest genetic research in Sweden focus on *Pinus sylvestris*, *Picea abies* and *Populus*, there are also studies on *Betula*. For instance, the continental-scale genetic structure and hybridization in six species was studied using nuclear simple sequence repeats (nSSRs) in the *Betula* genus across Eurasia[88].

The state of research and development on forest genetic resources is further described in section 11.6.

5.4 Needs, challenges and opportunities

Generally, there is a need for more knowledge on the current status and trends of genetic variation, especially in *Picea abies* and *Pinus sylvestris*.

Regarding genetic monitoring, several scientific, practical and economic issues need to be addressed and solved. These include a proper collection and storage of the collected tissues as well as applying appropriate methods that give relevant information concerning changes over time in heterozygosity levels and allele numbers in prioritized adaptive traits. Needs and challenges of genetic monitoring are further discussed in section 12.4.

5.5 Priorities for capacity building and research needs

Genetic variation along with species and ecosystem diversity comprise different levels of biodiversity. In general, there is no knowledge on which alleles that have an actual or potential value for the economy, environment, science and society. This is a reason to both conserve genetic variation in forest trees and to sustainably utilize it. Therefore, the Swedish Forest Agency should more systematically promote research needs to the government, universities and research institutions, primarily concerning the use (section 8.6.2), breeding (section 9.4) and management (section 10.4) of forest genetic resources.

[87] Wang J, Ding J, Tan B, Robinson KM, Michelson IH, Johansson A, Nystedt B, Scofiels DG, Nilsson O, Jansson S, Street NR & Ingvarsson PK. 2018. A major locus controls local adaptation and adaptive life history variation in a perennial plant. Genome Biology volume 19, 72.

[88] Tsuda Y, Semerikov V, Sebastiani F, Vendramin GG & Lascoux M. 2017. Multispecies genetic structure and hybridization in the *Betula* genus across Eurasia. Molecular Ecology. 26: 589–605.

6 *In situ* conservation of forest genetic resources

Part 3: State of forest genetic resources conservation

This chapter provides a narrative of the current state of *in situ* conservation of forest genetic resources, and the needs, challenges and opportunities for improving it in Sweden.

6.1 State of *in situ* conservation

Since 2013, the Swedish Forest Agency has conserved gene conservation units (GCU:s) of forest trees in habitat protection areas (Figure 15). These protected areas are, according to the national legislation, "*small land or water areas that are important environments for threatened plants or animals, or especially important to protect for other reasons*". The general aim with habitat protection areas is to protect the biological values.

The Swedish Forest Agency has a strategy for *in situ* gene conservation with targets for the number of GCU:s per tree species. GCU:s should also be evenly distributed within the species Swedish distribution area to conserve more of the genetic variation.

According to a gene conservation evaluation for period 2013–2018, over 600 GCU:s exists in approximately 430 habitat protection areas (Table 4). Mainly there are GCU:s of *Picea abies* (191) and *Pinus sylvestris* (122), followed by *Populus tremula* (53), *Fraxinus excelsior* (49) and *Fagus sylvatica* (40).

Figure 15. The Swedish Forest Agency conserves ecosystems, native species and their genetic variation at the same time in habitat protection areas. This is a resource efficient way to conserve forest genetic resources. Photo: Björn Ehrenrot (left) and Karin Ekströmer (right), the Swedish Forest Agency.

Table 4. Results of gene conservation in Sweden of native forest tree species in habitat protection areas during the period 2013–2018. GCU = the number of gene conservation units. 14 of 25 tree species need further *in situ* conservation. Source: the Swedish Forest Agency

Tree species	Number of GCU	Geographic spread of GCU in Sweden	Need of further gene conservation
Acer platanoides	3	Insufficient	Yes
Alnus glutinosa	25	Relatively sufficient	No
Alnus incana	10	Relatively sufficient	No
Betula pendula	8	Insufficient	Yes
Betula pubescens	24	Insufficient	Yes
Carpinus betulus	11	Sufficient	No
Coryllus avelana	9	Relatively sufficient	No
Fagus sylvatica	40	Sufficient	No
Fraxinus excelsior	22	Relatively sufficient*	Yes
Juniperus communis	2	Insufficient	Yes
Picea abies	191	Sufficient	No
Pinus sylvestris	122	Sufficient	No
Populus tremula	53	Sufficient	No
Prunus avium	5	Insufficient	Yes
Prunus padus	2	Insufficient	Yes
Quercus petrea	13	Insufficient	Yes
Quercus robur	49	Sufficient	No
Salix caprea	8	Relatively sufficient	No
Sorbus aucuparia	3	Insufficient	Yes
Sorbus intermedia	0	Insufficient	Yes
Taxus baccata	0	Insufficient	Yes
Tilia cordata	15	Relatively sufficient	No
Ulmus glabra	10	Relatively sufficient*	Yes
Ulmus laevis	0	Insufficient	Yes
Ulmus minor	0	Insufficient	Yes

*Additional gene conservation units are needed to conserve genetic variation in *Fraxinus* and *Ulmus* due to ash dieback and Dutch elm disease, respectively.

6.2 Organization and approaches used

Gene conservation is organized within the Swedish Forest Agency's ordinary work on protecting forest habitats. The areas selected for forest protection are in accordance with the Swedish national strategy for formal protection of forests[89]. Gene conservation should be consistent with the goal for the habitat protection area, i.e. how to conserve, manage and develop it.

Genetic conservation units (GCU:s) are registered in connection with the establishment of the habitat protection area. The trees in a GCU should be considered autochthonous to the site, i.e. not transferred, genetically improved or of foreign origin. They should occur in relatively well-defined stands and have such an age and vitality that they likely can contribute to the next generation.

Natural regeneration and management of the trees within the GCU are prerequisites for gene conservation. Management requirements of GCU:s should be determined approximately every ten years in connection to regular inspections of the protected areas. Management may include the removal of introduced tree species or to selectively harvest *Picea abies* without causing damage to the protected area in general. Also, the approximate number of reproductive trees and evidence of natural regeneration and forest damage should be documented.

The approach for *in situ* gene conservation is to register stands with a minimum number of trees that meet certain criteria. Guidelines for an adequate number of trees within a GCU are in accordance with those formulated by the pan-European cooperation project Eufgis[90]. Depending on the conservation purpose and characteristics of the tree species, Eufgis identifies different kinds of GCU:s. For instance, the number of trees in a GCU should be so large that the population has a sufficiently high genetic variation to avoid inbreeding and to survive and reproduce in the long term. The guidelines for GCU:s in the Swedish habitat protection areas also take into account which stand sizes that are possible to achieve[91].

The pan-European strategy for genetic conservation of forest trees intends to improve conservation in Europe and maintain the evolutionary potential of European forest tree species throughout their entire distribution ranges. Sweden and several other European countries have implemented the strategy, for example by establishing conservation units in areas where the strategy indicates that species are not sufficiently well conserved (Figure 16).

---

[89] Skogsstyrelsen. Nationell strategi för formellt skydd av skog. https://www.skogsstyrelsen.se/globalassets/aga-skog/skydda-skog/nationell-strategi-for-formellt-skydd-av-skog.pdf. Downloaded 2020-05-15.

[90] Bioversity International. European Information System on Forest Genetic Resources, EUFGIS, http://portal.eufgis.org/ Downloaded 2020-05-15.

[91] At least 500 reproductive individuals should be included in a gene conservation unit of *Picea abis*, *Pinus sylvestris* and *Betula*; at least 200 trees in gene conservation unit of *Populus* and *Alnus;* at least 50 trees of *Acer*, *Fagus, Fraxinus*, *Quercus* and *Tilia*); and at least 15 trees of *Juniperus* and *Prunus*, considering their small and isolated populations.

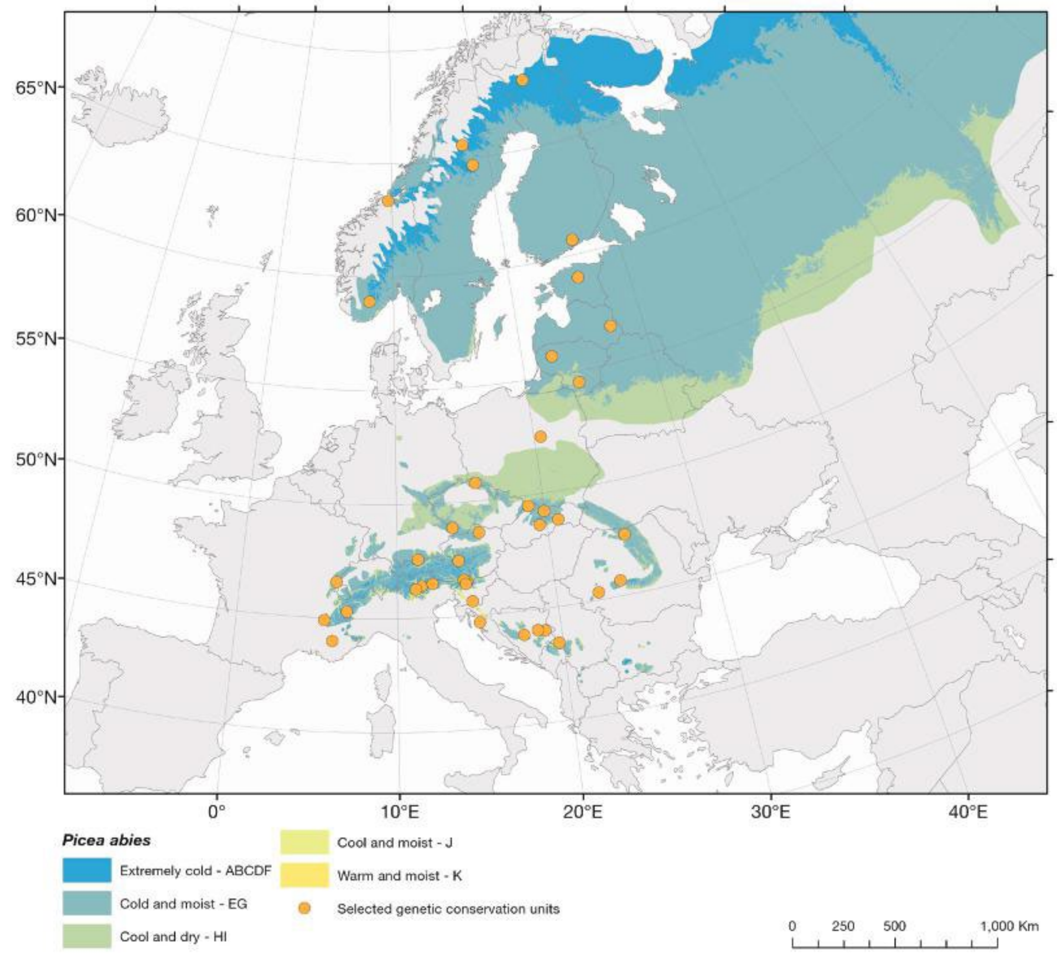

Figure 16. The Swedish contribution to the pan-European gene conservation strategy for *Picea abies*. The yellow circles show that there are gene conservation units in two out of three environmental zones in Sweden. Source: Euforgen[92].

The ambition in Sweden is to conserve all native tree species. Some of the most prioritized ones are *Fraxinus excelsior* and *Ulmus* due to their severe damage by ash dieback and Dutch elm disease, respectively. Also, tree species occurring with their northern marginal populations in Sweden are prioritized due to local genetic adaptation processes leading to valuable evolutionary potential. For instance, *Prunus avium*, *Sorbus intermedia, Taxus baccata*, *Quercus petrea* and *Ulmus minor* occur with northern peripheral populations in Sweden.

The Swedish Forest Agency is the main stakeholder in *in situ* gene conservation. Researchers can be regarded as potential stakeholders should they collect and analyze genetic material from the gene conservation units.

[92] From: de Vries SMG, Alan M, Bozzano M, Burianek V, Collin E, Cottrell J, Ivankovic M, Kelleher CT, Koskela J, Rotach P, Vietto L & Yrjänä L. 2015. Pan-European strategy for genetic conservation of forest trees and establishment of a core network of dynamic conservation units. European Forest Genetic Resources Programme (EUFORGEN), Bioversity International, Rome, Italy.

6.3 Needs, challenges and opportunities

Gene conservation in habitat protection areas is considered as a resource efficient method to conserve genetic variation for all time in native tree species. One drawback however is that these areas often are too small (less than ten hectares) to house any or sufficiently large stands of several minor tree species. Thus, gene conservation of species as *Sorbus intermedia* and *Taxus baccata* occurring in small and scattered populations require larger protected areas.

In Sweden, relatively large areas of forest land are protected mainly in national parks and nature reserves[93,94] (section 2.1.1). In practice, this includes gene conservation for many tree species. However, as gene conservation is not included as a purpose of the protected area, there is no assessments, documentation or management of the trees. Therefore, these areas do not fulfill the requirements for *in situ* gene conservation.

Generally, the size of a forest stand can be expected to have a positive correlation with the amount of its genetic variation. The large and geographically widespread nature reserves imply an increased possibility to find larger gene conservation units of most tree species as compared with what is found in the relatively small habitat protection areas. Gene conservation in nature reserves is however yet not possible partly due to potential restrictions in the Swedish environmental code and other national legislation.

Areas and individual trees with identified high natural values are generally excluded from forest management. The areas include forest impediments, woodland key habitats, voluntary forest set-asides and retention on harvested areas. Even though gene conservation is not included as an argument to exclude these areas they could in theory have an important function for gene conservation. The weaknesses of some of these forms of protection are mainly that they do not guarantee long-term protection, nor do they identify gene resources. Therefore, they do not meet the European criteria for gene conservation.

The knowledge on and economic resources for gene conservation of forest trees and other organism groups is generally limited to the relevant authorities and organizations concerned. Only rather general genetic knowledge however is required to enable gene conservation. Provided additional resources, it would be feasible to further educate officers involved with nature conservation management in protected nature reserves and national parks administrated by the Country Administrative Boards and the National Environmental Protection Agency, respectively.

[93] Frank A & Bergquist J. 2004. Naturskydd och skogligt genbevarande. Skogsstyrelsen, Rapport 11, 2004.

[94] Skogsstyrelsen, Naturvårdsverket, Statistiska Centralbyrån & Sveriges Lantbruksuniversitet. 2019. Statistik om formellt skyddad skogsmark, frivilliga avsättningar, hänsynsytor samt improduktiv skogsmark. Skogsstyrelsen Rapport 2019/18. In Swedish.

6.4 Priorities for capacity building

It is important to secure resources for nature conservation management in the habitat protected areas that house gene conservation units in Sweden. In 2018-2019, a nationwide survey was undertaken including over 12,000 formally protected habitat protection areas and nature conservation agreement with different forest types and landscapes[95]. The survey found that nature conservation management is neglected in more than half of these areas[96]. In one third of the areas, urgent efforts, such as clearing of *Picea abies* from deciduous forests, are needed.

Gene conservation units only exist in approximately 400 of the habitat protection areas, implying that the need of nature conservation management is far bigger than securing genetic values. Resources will also be needed to manage gene conservation units in an adequate way.

[95] In 2019, more than 13,500 habitat protection areas and nature conservation agreements exist in Sweden, totaling nearly 72,000 hectares.

[96] Emma Liljewall, Swedish Forest Agency, personal communication, 2020-03-23.

7 *Ex situ* conservation of forest genetic resources

This chapter presents the current state of *ex situ* conservation of forest genetic resources, and the needs, challenges and opportunities for improving it in Sweden.

7.1 State of and approaches used for *ex situ* conservation

Ex situ conservation in Sweden is carried out in a few stands and in seed orchards/clonal archives in breeding programs of *Picea abies* and *Pinus sylvestris*. The conservation is static and aims to conserve the individual genotypes, thus there is no natural selection or natural regeneration involved in the units.

A forest gene bank was established at the Swedish Forest Agency in 1980, following a proposal from the Government. The purpose was to conserve autochthonous genetic variation of forestry species widely influenced by transfer of forest reproductive material and tree breeding activities. The gene bank initially consisted of 67 *Picea abies* plantations and 171 naturally regenerated stands of *Pinus sylvestris*. In addition, *Quercus robur* and grafts of *Picea abies* from Southern Sweden were planted in sex clone archives, respectively.

As there was no agreement with landowners, low funding and limited management, only four *Quercus robur* archives remain today in the gene bank[97]. Except for conservation purposes, these archives will be used for further research and breeding activities. There is also a planting with *Ulmus* spp. that was previously established within an EU-project.

There are a limited number of *ex situ* systems purely for conservation purposes, however there are clonal archives for ten native and five introduced tree species (Table 5). Except for *Picea abies* and *Pinus sylvestris* with 36 and 76 archives, respectively, there are 1-2 archives of several other tree species. A DNA-archive is under preparation for founder trees within the breeding activities of *Picea abies* and in the future also for *Pinus sylvestris*.

The main stakeholders of *ex situ* conservation are the Forest Research Institute of Sweden (Skogforsk) and the Swedish Forest Agency.

---

[97] Black-Samuelsson S. 2019. Den skogliga genbanken – från storhetstid till framtid. Skogsstyrelsen Rapport 2019/3. In Swedish with an English abstract.

Table 5. Information on *ex situ* areas and accessions (seed bank, clonal archives) of native and introduced tree species in Sweden. Sources: The Forest Research Institute of Sweden and the Swedish Forest Agency

Tree species	Number of *ex situ* areas	Areal *ex situ* area (ha)	Number of *ex situ* accessions
Native tree species			
Alnus glutinosa	0	0	1
Alnus incana	0	0	1
Betula pendula	0	0	2
Betula pubescens	0	0	1
Larix sibirica	-	-	1
Picea abies	3	3	36
Pinus sylvestris	0	0	76
Populus tremula	0	0	2
Quercus robur	4	8	0
Sorbus aucaparia	0	0	1
Tilia cordata	0	0	1
Introduced tree species			
Larix decidua	0	0	1
Picea sitchensis	0	0	2
Pinus contorta	0	0	8
P tremula x tremuloides	0	0	2
Populus trichocarpa	0	0	2

7.2 Needs, challenges and opportunities

Forest geneticists in the Nordic countries currently have a dialogue concerning whether *in situ* conservation efforts are sufficient to secure forest genetic resources against future challenges such as climate change, pests and diseases[98]. Cryo preservation, or other *ex situ* conservation measures, may be an additional measure for the preservation of genetic resources at risk, such as *Fraxinus* and *Ulmus*, and will be further discussed.

[98] Friis Proschowsky G, Rusanen M, Tollefsrud MM, Sigurgeirsson A, Kroon J, Black-Samuelsson S, Bakkebø Fjellstad K, Solvin T & Hagalid B. 2020. Genetic conservation of forest trees in the Nordic countries. NordGen publication series: 2020:1.

8 The state of use

Part 4: State of use, development and management of forest genetic resources

This chapter describes the state of the use of forest genetic resources and the needs, challenges and opportunities in this area in Sweden. It also briefly describes how the production of forest reproductive material is organized and the trends in the production of and demand for forest reproductive material.

8.1 Marketing of forest reproductive material

The production and marketing of forest seed and plants within the EU is harmonized with the Council Directive 1999/105/EC[99] on the marketing of forest reproductive material and implemented in national legislation. The Swedish Forest Agency is the competent authority for the implementation of the Directive in Sweden.

According to the legislation, any natural or legal person professionally engaged in the marketing or importation of forest reproductive material (suppliers) should be registered at the official body. The Swedish Forest Agency conduct annual controls to supervise that the suppliers follow the regulations for forest reproductive material.

All seed produced in Sweden and other EU member states must come from officially approved and registered basic material (section 8.2), such as seed orchards or seed stands. A Master Certificate is issued by the national competent authority to each seed lot after collection. It assures that seeds are collected from an approved basic material and include information on the type of basic material, phenotypic and genetic quality and origin of the material. A Master Certificate is required to market forest reproductive material.

Suppliers delivering forest reproductive material are responsible to give the buyer the Master Certificate reference and other information needed for appropriate documentation of the material. This information is given on the label or a supplier's document. The aim is to ensure that the marketed material is traceable to the registered source of basic material throughout the whole chain, from production to end use.

A Master Certificate that is issued in one EU Member State is valid across the whole EU. When forest reproductive material moves from one Member State to another, the authority of the Member State from which the forest reproductive material is moved shall provide information about the identity and amount of traded forest reproductive material to the authority of the recipient Member State. The person or company trading forest reproductive material across member state borders shall notify the authority about the trade.

Forest reproductive material coming from countries outside the EU is regulated by an EU Council Decision (2008/971/EC). It may be imported to and marketed in

[99] Official Journal of the European Communities. Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0105&from=EN. Downloaded 2020-05-15.

the EU if it affords the same assurances as the material produced in the EU[100]. Before marketing within the EU, the competent authority must issue a Master Certificate based on the OECD Certificate of Identity or Certificate of Provenance. It is the importer's responsibility to ensure that the forest reproductive material fulfills plant health requirements.

A new package of EU legislation on plant health entered into force on December 14, 2019[101]. It includes more extensive rules on traceability of plant material moving into and within the EU, new plant passport rules and the introduction of a new kind of regulated harmful pests; regulated non-quarantine pests (RNQP). For the forestry sector, the inclusion of *Dothistroma* spp as an RNQP on *Pinus sylvestris* will be of relevance.

Other regulations and national instruments, such as strategies, advisory services and certifications concerning forest genetic resources are described in sections 11.4. and 11.5.

8.2 Basic material

Basic material includes the following types: seed source, seed stand, seed orchards, parents of families, clone and clonal mixture. The minimum requirements to approve basic material in the categories source-identified, selected, qualified and tested are described in the annexes of the Council Directive 1999/105/EC.

In Sweden, approximately 50 seed orchards are currently approved in the category "Tested", corresponding to about 20 % of the total number of seed orchards. Most seed orchards in the category 'Tested' are *Pinus sylvestris*, but there are also several tested seed orchards of *Picea abies* and *Betula pendula.* Moreover, there are tested clones and clonal mixtures of *Populus tremula* x *tremuloides*.

All approved basic material is listed in a national register, "Rikslängden". The EU compiles national registers of basic material for all EU Member States. This information is available on the EU web page FOREMATIS database[102].

[100] Forest reproductive material certified in Canada, Norway, Serbia, Switzerland, Turkey and United States following the OECD certification rules (OECD Forest Seed and Plant Scheme) fulfill these EU equivalence requirements.

[101] European Commission. Plant health and biosecurity. New EU plant health rules, https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation/new_eu_rules_en. Downloaded 2020-05-15.

[102] European Commission. FOREMATIS - Forest Reproductive Material Information System http://ec.europa.eu/forematis/. Downloaded 2020-05-15.

8.3 Production, use and demands

Since 1998, the Swedish Forest Agency makes an annual survey regarding the deliveries of tree seedlings for forest cultivation[103]. The survey is conducted among companies that produce and/or market forest reproductive material. The statistics include the number of delivered seedlings by tree species, by method of production and by provenance.

8.3.1.1 Plant delivery

During 1998–2019, about 351 million of forest seedlings were delivered on average per year (Table 6, Figure 18). *Picea abies* dominated with an average of 199 million seedlings annually (171-236 million per year), followed by *Pinus sylvestris* averaging 135 million (115-175 million per year). During the same period, the deliveries of other conifer species mainly *Pinus contorta*, and deciduous trees, mainly *Betula* amounted to about 15 million and 2.9 million plants per year, respectively.

During 2019, approximately 381 million seedlings were delivered, primarily of *Picea abies* (51 percent) and *Pinus sylvestris* (46 percent) (Table 7). Seedlings from deciduous trees represented only 0,6 percent and from *Pinus contorta* 1.8 percent. Most of the seedlings were delivered as rooted plant material and the provenance of the seeds was mainly Swedish.

Figure 18. Green house cultivation of forest reproductive material. During 1998–2019, 351 million forest seedlings were delivered on average annually, mostly of *Picea abies* and *Pinus sylvestris* (averages of 199 and 135 million seedlings, respectively). Photo: Sanna Black-Samuelsson, the Swedish Forest Agency.

[103] Östberg K. 2020. Production of seedlings 2019. Statistical report. JO0313 SM 2001. ISSN 1654–402. Swedish Forest Agency. In Swedish with an English abstract.

Table 6. Numbers (in million) of delivered seedlings of various tree species in Sweden during 1998–2019. In 2011, *Pinus contorta* was separated from "Other conifers" and *Betula* spp. was separated from "Other deciduous trees". Source: the Swedish Forest Agency

Year	*Pinus sylvestris*	*Picea abies*	*Pinus contorta*	Other conifers	*Betula* spp.	Other deciduous trees	Sum
2019	172,5	194,7	6,6	4,7	1,3	1,0	380,9
2018	174,7	194,7	6,8	5,4	1,3	1,0	383,8
2017	162,0	197,9	8,1	4,7	1,1	1,2	375,1
2016	157,2	171,6	8,6	4,1	1,6	1,7	344,8
2015	144,7	182,2	9,3	4,6	1,7	1,7	344,2
2014	148,9	199,6	12,0	5,2	1,6	2,0	369,2
2013	138,4	215,5	16,1	7,0	1,4	2,5	380,9
2012	128,5	217,3	18,0	7,0	1,3	2,2	374,1
2011	132,7	225,1	16,2	7,3	0,9	1,9	384,0
2010	123,9	219,4	..	22,3	..	2,9	368,5
2009	127,2	226,7	..	23,0	..	3,5	380,3
2008	126,8	236,0	..	17,6	..	3,0	383,4
2007	117,1	231,7	..	15,0	..	3,4	367,1
2006	117,0	199,0	..	12,0	..	2,7	330,7
2005	125,0	194,0	..	10,5	..	1,4	330,9
2004	126,0	188,0	..	10,0	..	2,0	326,0
2003	119,0	186,0	..	11,0	..	3,1	319,1
2002	115,0	172,0	..	10,0	..	2,8	299,8
2001	124,0	172,0	..	12,0	..	3,0	311,0
2000	125,0	187,0	..	11,0	..	2,9	325,9
1999	124,0	171,0	..	8,0	..	1,8	304,8
1998	139,0	188,0	..	10,0	..	2,8	339,8

8.3.1.2 Genetically improved material

The supply of genetically improved forest reproductive material relies on the tree improvement programs on a national level and on improved material from neighboring countries having suitable climate conditions.

Genetically improved material is characterized by being the offspring of selected plus trees based on their wood production capacity, survival and quality traits (Chapter 9). Depending on species and site, it may also for traits like growth and survival be characterized by transfer effects, relative local unimproved material . As an outcome of the tree improvement programs, the third round of seed orchards has now been established with a potential gain in wood production of 20-25%[104].

[104] Rosvall O, Andersson Gull B, Berlin M, Högberg K-A, Stener L-G, Jansson G, Almqvist A & Westin J. 2016. Skogsskötselserien nr 19, Skogsträdsförädling. Skogsstyrelsen.

The share of genetically improved seedlings from seed orchards of *Pinus sylvestris* and *Picea abies* for forest regeneration has increased steadily in the 2000s (Table 7). For *Pinus sylvestris*, genetically improved seedlings account for more than 90 percent of total plant production since 2012, exclusively from Swedish seed orchards. In Sweden, it is only the most northerly parts of the country that lack seed supply of genetically improved, sufficiently hardened plant material.

For *Picea abies*, the share of genetically improved material from Swedish and foreign seed orchards has varied between 37 and 79 percent since 2001. The annual variation is mainly due to the irregular flowering and damage to flowers, cones and seeds. During this period, the share of genetically improved seeds has, except for 2018, steadily increased at the expense of the share of seeds from Swedish and foreign stands.

Table 7. Share of produced seedlings of the two main forest tree species in Sweden, *Pinus sylvestris* and *Picea abies*, by seed orchards, stands and provenance (Swedish or foreign) during 2001-2019. NA = data not available. Source: the Swedish Forest Agency

	Pinus sylvestris					***Picea abies***				
	Swedish		Foreign		NA	Swedish		Foreign		NA
Year	Seed orchard	Stand	Seed orchard	Stand		Seed orchard	Stand	Seed orchard	Stand	
2019	97	2	0	0	0	67	7	11	12	4
2018	98	1	0	0	0	56	8	9	24	4
2017	98	1	0	0	0	58	12	9	18	3
2016	95	4	0	0	0	62	8	17	10	4
2015	94	5	0	0	0	62	18	10	7	3
2014	95	5	0	0	0	67	16	10	7	0
2013	91	8	0	0	0	69	12	5	13	0
2012	90	10	0	0	0	69	10	7	15	0
2011	83	15	0	0	2	57	9	5	22	7
2010	85	14	0	0	0	59	13	5	19	4
2009	81	18	0	1	0	56	13	6	24	0
2008	83	16	0	1	0	47	15	7	32	..
2007	80	20	0	0	0	48	14	1	37	0
2006	78	22	0	0	0	47	17	2	34	0
2005	68	24	..	..	9	50	21	12	17	0
2004	74	26	0	0	0	50	25	1	22	7
2003	81	19	0	0	0	45	23	3	27	2
2002	63	37	0	0	0	41	23	2	32	2
2001	60	36	0	0	4	36	33	1	26	4

8.4 Trade within the EU and import

Forest reproductive material is regularly traded to Sweden across the borders of the EU Member States and is also imported to Sweden from a few countries outside the EU (Table 8). Over the last decade, more than 7 tons of *Picea abies* seed have been imported, mainly from Belarus (nearly 4 tons). During the same period, more than 4.1 tons of *Pinus sylvestris* seeds were obtained, mainly from Finland. There is a large annual variation in the import.

Table 8. Amount (kg) of seeds of *Picea abies* and *Pinus sylvestris* that were traded to Sweden across EU Member State borders or imported from third countries to Sweden during year 2011 to 2019. [1] The country from which the seeds originate from, i.e. not necessarily the exporting country. Source: the Swedish Forest Agency

Species, country[1]	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
P. abies	**254**	**154**	**286**	**740**	**1 220**	**1 049**	**590**	**729**	**2 049**	**7 071**
Belarus	10	40	50		311	799	300	635	1 843	3 987
Denmark	12	17	2	2		2	4	3	2	44
Finland	43		168	498	251				66	1 026
Latvia					529					529
Lithuania	189	47	56	80	111	228	262	91		1 064
Norway		50	10	10	19	20	24			133
Poland				150					138	288
P. sylvestris	**189**	**738**	**381**	**921**	**134**	**1 519**	**94**	**11**	**180**	**4 168**
Denmark		4								4
Finland	189		381	921	134	1 519	94	11	180	3 430
Norway		734								734
Total sum	**443**	**892**	**667**	**1 661**	**1 354**	**2 567**	**685**	**740**	**2 229**	**11 240**

8.5 Needs, challenges and opportunities

Forest reproductive material has been transferred to Sweden since the second half of the 19th century. Genomic analysis using single-nuclear polymorphisms has been used to study forest reproductive material transfers and demographic history in *Picea abies*[105]. The results confirm the conception that a large share of the trees selected in Southern Sweden to establish seed orchards has an origin from recent introductions from Central Europe. The ancestry of *Picea abies* in central and southern Sweden largely trace back to the Alpine or the Carpathian domain. This reflects the translocations from central Europe during the massive reforestation which occurred in the 20th century[106]. Since the 1950s, Sweden and Norway have imported forest reproductive material (seeds) from Belarus, Czech Republic, Germany, Slovakia and the Baltic States.

Genetically improved and transferred forest reproductive material has become more prevalent in the Swedish landscapes over time. Information on the

[105] Chen J, Li L, Milesi P, Jansson G, Berlin M, Karlsson B, Aleksic J, Vendramin GG & Lascoux M. 2019. Genomic data provide new insights on the demographic history and the extent of recent material transfers in Norway spruce. Evolutionary Applications 12:1539–1551.

[106] Myking T, Rusanen M, Steffenrem A, Kjaer ED & Jansson G. 2016. Historic transfer of forest reproductive material in the Nordic region: drivers, scale and implications. Forestry 89: 325-337.

geographic location of this material (where it is planted), and its origin and expected response to transfer, such as the effect of a latitudinal transfer on growth performance and shoot phenology is therefore of increasing importance for several reasons. One example is that it enables modelling of future forest growth. Trials of forest reproductive material are usually set up under more optimal growth conditions than is the case in practical forestry. Therefore, the representativity of the test results from such trials for practical forestry can be rather uncertain. Another example is the possibility to assess the need of managing risks in forest cultivation such as those related to climate change and diseases.

Today there is no official information concerning the origins of seedlings in the Swedish forests, even though some forest owners might save the records (Figure 19). Neither is it known how large an area within a given region that is cultivated with transferred provenances or genetically improved material is or from which breeding cycle it is derived. Also, information about the share of naturally regenerated trees within planted forests is lacking.

According to an analysis based on national data, millions of plants and large amounts of seed from forest trees have been transported in the European trade[107]. The results showed that Sweden was one of the dominating countries in the cross-border trade of *Picea abies* and *Pinus sylvestris*. It was concluded that the possibilities are limited to predict the genetic influence of the transferred forest reproductive material. If the material could be documented, the authors noted that it would "*virtually transform European forests into a huge number of provenance and growth trials, which would significantly improve our understanding of tree species performance and their reaction norms towards climate change*".

8.6 Priorities for capacity building and research

8.6.1 Traceability of forest reproductive material

There are different ways forward to improve the traceability of forest reproductive material. One possibility is that the buyer of the material should document the Master Certificate number in a forest management plan. This might already occur to a certain extent today, especially among large forest companies.

The administrative registers with information on Master Certificates (provided they can be conveniently classified), and seed imports of forest reproductive material could be utilized to gain knowledge on the forest tree origin. Master Certificates could be categorized into seeds derived from stands or seed orchards and which round of seed orchard the seeds derive from or, if available, estimated. Future breeding activities will however not have the same distinct breeding cycles as today. Additionally, occasionally only a fine selection of clones are chosen from a seed orchard for seed production, based on their high performance with regard to specific characters. These clones will not be representative of the total genetic variation in the seed orchard. This fraction should be registered and approved as new basic material.

[107] Jansen S, Konrad H & Geburek T. 2019. Crossing borders – European forest reproductive material moving in trade. Journal of environmental management 233: 308-320.

Figure 19. Over 300 million of forest seedlings are planted every year in Sweden, mainly of genetically improved *Picea abies* and *Pinus sylvestris*. Today there is no official documentation of the forest reproductive material planted. This calls for the development of an appropriate method to document the plant identity. In this way, the evaluation of forest cultivation, both in terms of production and environmental aspects, would be facilitated for forest owners, researchers and authorities. Photo: Michael Ekstrand.

Using genomic markers, it is possible to identify and track the origin of forest reproductive material of *Picea abies* and *Pinus sylvestris*. This type of data would in the future enable investigations of the genetic adaptive effects of translocation, which is important for tree breeding, conservation and forest management under climate change. This idea however requires a developed infrastructure to manage, transport and store needles and DNA samples in a resource efficient and appropriate way.

Clearly, documenting the forest reproductive material used in forest cultivation would enable the evaluation of material, both in terms of production and environmental aspects. This would be of considerable value for forest owners, forest tree breeders, researchers and authorities. For instance, this would enable an assessment of whether there are genetic causes to certain forest damage, such as abnormal shoot formation[108]. The idea of developing a system for documenting forest reproductive material needs further consideration before it can be used to generate credible data.

[108] Growth disturbance in juvenile shoots, where genetically improved *Pinus sylvestris* have been found to have a higher frequency of double shoots and a greater tendency to have proleptic shoots than naturally regenerated plants (Högberg 2019).

8.6.2 Research priorities

The extensive transfers of forest reproductive material from a wide geographical scale have to a great extent affected the native gene pools in *Picea abies* in southern Sweden. In other parts of Sweden, it is also possible that the extensive transfers of forest reproductive material from different geographic origins have affected the native gene pools in *Pinus sylvestris* and *Picea abie*s. According to analyses of planted forest data[109] from the 2015 Forest Research Assessment, Sweden has the fifth largest total planted forest area in the world[110] and takes a special position in Europe in this regard. This justifies various analyses of forest reproductive material.

As the use of genetically improved *Pinus sylvestris* and *Picea abie*s continues to increase owing to their superior growth potential, there is also an emerging need of empirical and scientific studies on damage levels and resistance to pests. Also, genetic correlations between traits included in the breeding programs and several other traits of importance need to be studied further. Traits involved in resistance to various existing and new pests and diseases and to adaptation to extreme weather events are the most prioritized to analyze, in other words, traits necessary for the long-term survival of forest ecosystems.

An additional research need concerns an overall assessment of the number of cultivated plants that originate from a single seed orchard or a given set of parents. Focus could be on the seed orchards that for several years have produced large seedling numbers for forestry in relatively limited geographical areas. This could provide some information about the resilience of the forest in a long-term perspective. Related to this issue is addressing the extent to which individual clones in a seed orchard are represented at seed harvest, i.e. whether clones contribute in a proportionate way (panmixia). Such information would increase the possibility to manage an unbalanced clonal representativeness in the seed lot.

---

[109] Planted forests are defined as forest that are predominately composed of trees established through planting and/or deliberate seeding, where the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity.

[110] Payn T, Carnus JM, Freer-Smith P, Kimberley M, Kollert W, Liu S, Orazio C, Rodriguez L, Neves Silva L & Wingfield MJ. 2015. Changes in planted forests and future global implications. Forest Ecology and Management 352: 57–67.

9 The state of genetic improvement and breeding programs

This chapter provides a narrative on the current state of tree improvement and breeding programs in Sweden, as well as the needs, challenges and opportunities in this area. This chapter also describes how tree improvement and breeding programs are organized, and who the main players and stakeholders are.

9.1 Approaches, prioritized uses and traits

Forest tree breeding in Sweden began on a small scale in the 1930s with selection of plus-trees in natural stands and subsequent establishment of grafted plus-tree seed orchards. The production of genetically improved seeds from this first round of seed orchards started during the 1940s and 50s. The selected plus-trees for each of the main species constitutes the base population available for breeding. The base population was enlarged in the 1980s by selection of plus-trees distributed over most of the forest land area of Sweden. From the base populations a pre-defined number of trees have been selected as founder trees to nationwide breeding populations. All future breeding will be based on these founder trees and for the trees in the base population with a Swedish origin the ambition is to maintain them as grafts or as extracted DNA.

The breeding follows a multiple breeding population strategy based on sub-division of the nationwide breeding population into separate breeding populations of similar size and not allowing exchange of genetic material between populations. Each breeding population has its pre-defined target profile in terms of temperature climate (determines the vegetation period) and photoperiod (dependent on the latitude). Some of the breeding populations target temperature climates outside the current conditions as a preparation for future climates. The general breeding objectives with the tree improvement programs is to improve production, adaptation and improve or maintain wood quality. For the main tree species, production usually translates into production of timber and pulpwood, for other species also fuel wood and non-wood products (Table 9).

In each population, breeding is carried out in breeding cycles from which genetically improved trees can be utilized for deployment. The dominating form of deployment is establishment of seed orchards for large-scale production of improved seeds. The Swedish forest tree breeding has so far achieved three rounds of seed orchard establishment, sometimes also referred to as "generations" of seed orchards. A complete breeding cycle takes about 20-25 years, and for each generation the genetic gain in productivity increases with about 10 percent[111].

The third round of seed orchards that have now been established are entirely based tested material, i.e. clones selected based on their performance in genetic field trials for the production of tested seed. As these new seed orchards of tested clones are moving into production phase, they will replace older seed orchards of

[111] Rosvall O, Andersson Gull B, Berlin M, Högberg K-A, Stener L-G, Jansson G, Almqvist A & Westin J. 2016. Skogsskötselserien nr 19, Skogsträdsförädling. Skogsstyrelsen. In Swedish.

clones in the improved category, and the share of tested seed produced in Sweden will increase in the coming decades.

Well-developed breeding programs are available for the two major species *Picea abies* and *Pinus sylvestris*, and also for *Pinus contorta* and *Betula pendula*. For minor species such as *Larix* spp., *Quercus*, *Fagus sylvatica*, *Populus* and hybrids, *Fraxinus excelsior*, *Prunus avium*, *Picea sitchensis* and *Pseudotsuga menziesii* there is some intermittent breeding activity. For other tree species, which represent a small share of the forest reproductive material, there is very limited breeding activity[112].

The breeding program for *Pinus sylvestris* includes 24 separately managed breeding populations with specified target profiles related to temperature climate (degree-days) and photoperiod (latitude) regimes. Each breeding population comprises approximately 50-60 clones, indicating that there are more than 1 000 founder *Pinus sylvestris* trees in Sweden. The breeding strategy is primarily based on double-pair mating and progeny testing or a combination of progeny testing and clonal testing.

The *Picea abies* breeding program is organized into 22 separately managed breeding populations with specified target profiles based on temperature climate and photoperiod as for *Pinus sylvestris*. Each breeding population comprises approximately 50-60 clones, indicating that there are more than 1 000 founder *Picea abies* trees in Sweden. The breeding strategy is based on clonal testing and primarily a double-pair-mating design using 50-60 parents in each breeding population. About 650 field trials with *Picea abies* have been established during the development of the breeding program.

The breeding programs in Finland and Sweden exchange some breeding material such as seeds and performance data such as field trial data. For both *Pinus sylvestris* and *Picea abies*, the web-based deployment guidance tool Planter's Guide' has been developed. For *Pinus sylvestris*, the tool has been further developed to provide recommendations of the best seed orchards in both Sweden and Finland[113]. The tool allows the user to select a planting site, in the shape of a 3x3 km grid, and compare the production potential of seed sources from both countries[114]. The comparison can be made in the current climate as well as in various future climate scenarios. The production recommendations utilize transfer functions based on results from established provenance trials. In addition, artificial freeze tests are conducted on mainly young seed pine orchards to test the autumn hardiness of first year seedlings of annual bulk seed crops in order to fine tune the deployment of the seed orchard crops.

---

[112] Rosvall O & Stener LG. 2013. Förvaltning av lövträdens genresurs - anpassning till förändrat klimat och behov Arbetsrapport. Skogforsk. In Swedish.

[113] Skogskunskap. Plantvall Tall. https://www.skogskunskap.se/rakna-med-verktyg/foryngring/plantval-tall/. Downloaded 2020-05-15.

[114] Berlin ME, Persson T, Jansson G, Haapanen M, Ruotsalainen S, Bärring L & Andersson Gull B. 2016. Scots pine transfer effect models for growth and survival in Sweden and Finland. Silva Fennica 50. Article id 1562.

In each breeding population of *Picea abies* and *Pinus sylvestris*, families are tested in 4-5 genetic field trials as progenies or cloned progenies. Consequently, more than 100 tests in total are performed for each trait, species and generation. The breeding programs focus on quantitative traits, mainly area-based growth, adaptation to climate and common pests, and wood characteristics. The assessments provide knowledge on genetic parameters such as trait heritability and correlations between traits.

The standard procedure for assessment of field trials is a primary assessment at a young age (6-9 years) and a secondary assessment at 10-20 years. Some suitable trials series are selected to be assessed at an older age to provide genetic parameter estimates for mature traits, genetic age-age correlations and estimation of full rotation performances. The primary assessment allows for collection of scions for grafting of the best four clones within each family and the secondary assessment allows for a final selection of the best clone of the four previously selected. After promotion of growth and flower stimulation, the clones are ready to contribute in an artificial crossing scheme to generate the next breeding generation.

Table 9. Forest improvement programs mainly for native tree species with different objectives in Sweden. For species other than *Picea abies*, *Pinus sylvestris*, *Pinus contorta* (exotic) and *Betula pendula*, limited improvement activities are carried out.
Source: The Forestry Research Institute of Sweden

	Objective with improvement program		
	Timber	Pulpwood	Energy
Major forestry species			
Picea abies	X	X	
Pinus sylvestris	X	X	
Betula pendula	X	X	
Pinus contorta	X	X	
Minor forestry species			
Acer platanoides	X		
Alnus glutinosa	X		
Betula pubescens	X	X	
Fagus sylvatica	X		
Fraxinus excelsior	X		
Populus tremula x P. tremuloides	X	X	X
Populus spp.		X	X
Prunus avium	X		
Querqus petrea	X		
Querqus robur	X		
Tilia cordata	X		

9.2 Organization, main players and stakeholders

Tree breeding is jointly carried out by all Swedish forest owner categories. It is supported by the government and operated by the Forestry Research Institute of Sweden, Skogforsk. The forestry sector and the government negotiate a four year research and development program. Advisory groups with representatives of landowners influence the annual research and development programs. The responsibility for funding the seed orchard programs has shifted over time, from governmental to more private funding. The ownership of a seed orchard is dependent on the composition of land-owners in the intended deployment area which means they are jointly owned by for instance state owned companies and the private sector.

Regarding information systems for the tree breeding programs and intraspecific genetic variation patterns, there is a large database with all surveyed data (phenotypic data) and pedigree data for *Pinus sylvestris, Pinus contorta*, *Picea abies* and *Betula pendula*, and to some extent also for *Larix sibirica*. The database is associated with a tool for genetic analysis

Archives for conservation, breeding and supply of regeneration material for mass propagation facilities support the forest tree breeding programs. These archives exist mainly in two localities in Sweden (Sävar and Ekebo). Two cold storages at these locations support the breeding program for long term storage of seeds mainly from the major forest trees. There is also short-term storage of cleaned and treated seed orchard seeds to improve germination.

9.3 Current and emerging technologies used

Genomics is an emerging technology in forest tree breeding. Genomic selection could considerably shorten the breeding cycle by accelerating flowering at an early age. The method involves model building using a reference (or training) population that is phenotyped and genotyped using dense DNA markers. The model can be used to predict breeding values or genotypic values in a related breeding or propagation population using information from DNA markers.

To implement genomic selection and improve flowering using genomics, further basic research is needed to identify genes involved in mediating early flowering. This can be achieved by using genome-wide association studies based on genome-wide dense markers derived from genome re-sequencing in large diversity populations. One criterion to enable this is access to a high-quality reference genome to allow the identification of alleles.

There is also ongoing development of the technique somatic embryogenesis to root cuttings of *Picea abies* clones[115]. The implications for the management of using these clones in Swedish forestry has recently been described[116].

[115] Rosvall O, Bradshaw RHW, Egertsdotter U, Ingvarsson PK & Wu H. 2019. Using Norway spruce clones in Swedish forestry: introduction. Scandinavian Journal of Forest Research. 34: 333–335.

[116] Rosvall O, Bradshaw RHW, Egertsdotter U, Ingvarsson PK, Mullin TJ & Wu H. 2019. Using Norway spruce clones in Swedish forestry: implications of clones for management, Scandinavian Journal of Forest Research, 34:5, 390-404, DOI: 10.1080/02827581.2019.1590631.

In conclusion, traditional tree breeding methodologies will be the basis for tree improvement in the foreseeable future, but new genetic technology can support traditional breeding in a long-term perspective.

9.4 Priorities for capacity building and research

The lack of breeding programs and seed supply for tree species for which the economic incentives are weak makes it difficult for forest owners to adapt the choice of forest reproductive material to climate change. Therefore, there is a need to develop breeding programs for additional tree species, for instance hardwoods such as *Quercus robur*, *Fagus sylvatica* and *Alnus* spp.

The genetic variation within *Pinus sylvestris* and *Picea abies* is utilized in the breeding programs to adapt the breeding populations to future climates. The recommended choice of forest reproductive material in Planter's choice is also a means to apply climate assisted migration today for a future climate. Clonal variation in resistance to pests and the genetically inherited resistance can be used in breeding to achieve more resistant trees. This applies to ash dieback in *Fraxinus excelsior*[117] as well as the rust fungi *Cronartium flaccidum* and *Peridermium pini*, blister rust in *Pinus sylvestris.* The genetic variation in resistance/tolerance in *Pinus sylvestris* to blister rust is important to utilize, for example to adapt the clonal composition in seed producing seed orchards, as blister rust threaten large areas of *Pinus sylvestris* in northern Sweden.

Genetic variation in resistance provides the opportunity to breed for individuals with low susceptibility to certain pests. It is important to work more actively with the issue of resistance in breeding programs and to try to ensure that genes of importance for resistance to existing and new problematic pests are identified and maintained as far as possible.

[117] Stener L-G. 2012. Clonal differences in susceptibility to the dieback of *Fraxinus excelsior* in southern Sweden. Scandinavian Journal of Forest Research 28: 205-216.

10 Management of forest genetic resources

This chapter provides a narrative on how genetic aspects are considered mainly in cultivated forests. The needs, challenges and opportunities for improving the management of forest genetic resources are identified.

10.1 Genetic considerations in forest management

Forestry has a large impact on the forest genetic resources. The Forestry Act gives limited detailed requirements concerning which tree species and forest management methods to use. Consequently, the forest owners can to a large extent choose different tree species, forest reproductive material and management methods to regenerate, clear, thin and harvest forest genetic resources.

10.1.1 Aspects on regeneration

Since 2000, forest regeneration with genetically improved material has increased steadily[118] (section 8.3.1.2). The use of genetically improved *Picea abies* has increased from 37 percent in 2001 to 78 percent in 2019. During the same period, the use of genetically improved *Pinus sylvestris* increased from 60 to 97 percent.

Official statistics has provided the following data and trends concerning various aspects of regeneration[119]: The proportion of regeneration areas that fulfill the requirements under the Forestry Act shows a positive development since 1999 when a survey started. The latest three-year average revealed that 91 percent of the area was approved, often as a result of supplements of naturally regenerated plants. Planting is the method with the highest proportion of approved regenerations (92 percent), followed by sowing and natural regeneration (87 and 84 percent of the area approved, respectively). On areas where no measures are taken, the level of approved regeneration was 55 percent. Moreover, the share of regeneration areas where soil scarification is used prior to planting continues to increase. The share of soil scarification area of planted and naturally regenerated areas account for 89 and 62 percent, respectively.

The share of planting has increased steadily from around 60 percent in the early 2000s to 84 percent in 2016/17-2018/19 (Figure 20). During this period, the proportion of natural regeneration, especially methods where seed trees/ shelter trees are left for regeneration, decreased from 33 to 10 percent. The Forestry Act states that a minimum number of main plants (potential future crop trees) per hectare should be planted, seeded or naturally regenerated based on the site index. The latest results show that there are on average nearly 2 500 main plants per hectare in regeneration areas dominated by *Pinus sylvestris* and *Picea abies*. The plant number per hectare varies between 900 on poor sites and 2 300 on rich sites.

[118] Östberg K. 2020. Production of seedlings 2019. Statistical report. JO0313 SM 2001. ISSN 1654–402. Swedish Forest Agency. In Swedish with an English abstract.

[119] Svensson L. 2018/2019. 2019. Quality of regrowth. Statistical report. JO0311 SM 1901. ISSN 1654–4021. Swedish Forest Agency. In Swedish with an English abstract.

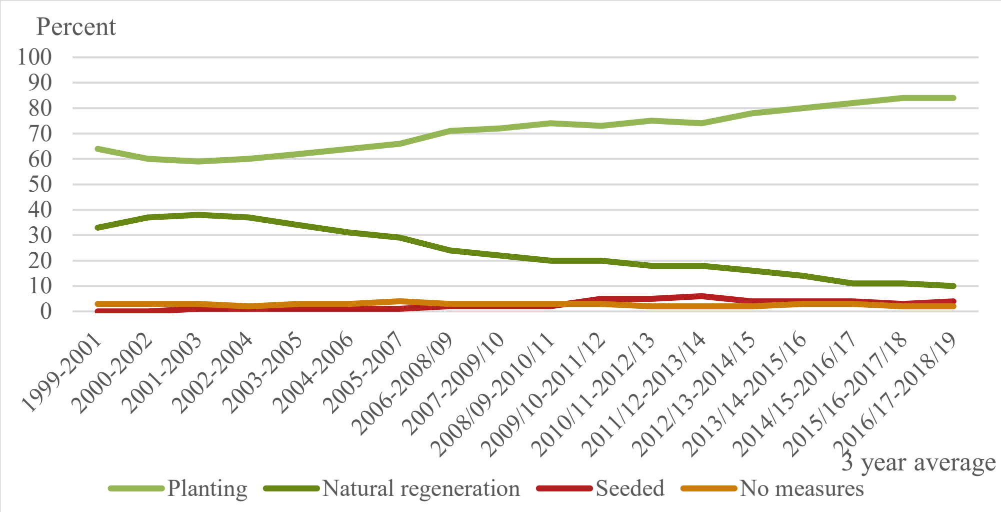

Figure 20. Planting is the dominant method for regeneration in Sweden and has increased from around 60 percent in the early 2000s to 84 percent in 2018. The proportion of natural regeneration has gone in the opposite direction and is down to ten percent. Seeding is used on about three percent of the harvested area. Source: the Swedish Forest Agency.

10.1.2 Clearing and thinning

Forest management through clearing and thinning also affects forest genetic resources (Figure 21). In 2017, the forest area included in clearing, planting activities, scarification and fertilization was approximately 756 000 hectares[120]. The area in thinning was the largest of the sylvicultural activities and corresponded to approximately 313 000 hectares in 2017.

Forest stands are cleared once, several times or sometimes not at all. There is no systematic follow-up or documentation concerning how much of the planted material that is left after clearing. There are indications that on average approximately 60-70 percent of the planted forest plants have survived and are vital about five years after regeneration. Remaining forest plants especially *Pinus sylvestris*, have died or are severely damaged by moose browsing and various pests and diseases. Naturally regenerated plants of *Picea abies*, *Pinus sylvestris* and deciduous tree species often start growing in the gaps in the forest stands that then occur.

At clearing, plants with the best developmental potential are often chosen to remain and form the future stand. The stands will later be thinned one to three times and a further portion of the planted trees will then be removed.

It is uncertain to what extent the development in the planted stands (described above) also applies to genetically improved plants. There is no data concerning whether the higher growth ability of the genetically improved seedlings make them more competitive than naturally regenerated plants of *Picea abies*, *Pinus sylvestris* and deciduous trees, or if the share of genetically improved trees in the remaining stand decrease over time.

[120] Forest statistics 2019. Official statistics of Sweden. Swedish University of Agricultural Science. Umeå 2019.

10.1.3 Harvesting

The harvested volume in Sweden during the period 2013/14 to 2017/18 was about 80 million m³o.b.[121]. Final felling accounted for the largest share (60 percent) of the harvested volume. In terms of area, thinning was dominating with some 313 000 hectares annually, followed by clearing (255 000 hectares) and final felling (187 000 hectares)[122]. The percentage of harvested volumes of *Picea abies* and *Pinus sylvestris* during this period were 55 and 33 percent, respectively. The remaining felled volumes of broadleaved trees accounted for some 12 percent of the total harvested volume.

In 2019, forest owners notified about 262 000 hectares for final felling which was a decrease of 10 percent compared to 2018[123]. This number does not correspond to the numbers of actual final felling mentioned above. Not all areas notified for final felling will be harvested and there is also a time lag from notification to harvesting. However, the area notified for final felling could be used as an early indicator on the trend in near time. The reduction is partly due to large areas of forests being damaged by fire in 2018. Infestation of the European spruce bark beetle and storm felling affected also the final fellings in 2019. In addition, forest owners applied for permits for felling of about 3 000 hectares of mountainous forest and on nearly 1 500 hectares of valuable broad-leaved forest.

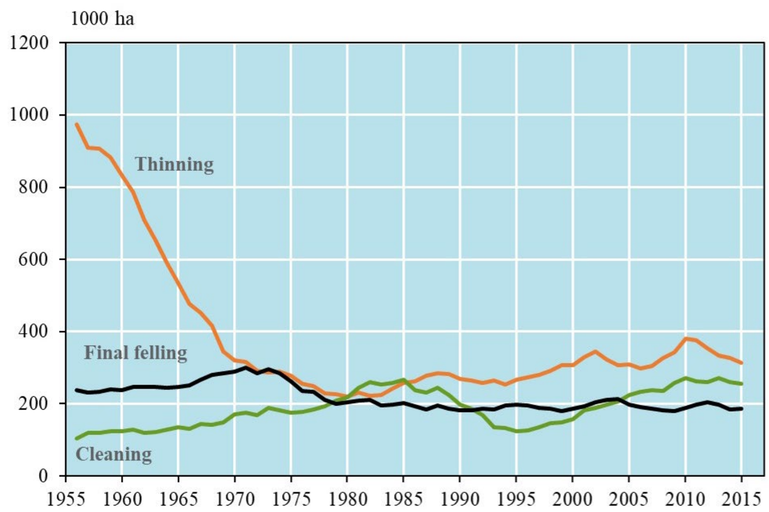

Figure 21. Annual harvesting area (hectare) by felling type by year in Sweden from 1955 to 2015. Source: The National Forest Inventory.

[121] Ekberg K. 2019a. Gross felling in 2017 and preliminary statistics for 2018. Statistical report JO0312 SM 1901. Swedish Forest Agency. In Swedish with an English abstract.

[122] Forest statistics 2019. Official statistics of Sweden. Swedish University of Agricultural Science. Umeå 2019.

[123] Ekberg K. 2019b. Notified areas of final felling in 2019. Statistical report JO0314 SM 2001. Swedish Forest Agency. In Swedish with an English abstract.

10.1.4 Traditional management techniques

Planting is almost exclusively done manually, while clearing mostly is motor-manual work. Thinning is mainly mechanized (Figure 22). The selection of which trees to include in the future forest are to a great extent carried out by a more or less trained workforce. Generally, they have limited possibilities to determine which plants or trees are planted and genetically improved. There is no indication of a major change in the existing silvicultural methods chosen. However, there are significant and gradually increasing difficulties in recruiting the necessary workforce. So far, the problem has been solved by recruiting workers for planting and clearing from other countries, mainly from Eastern Europe.

The prerequisites for a complete mechanization of forest management are to a large extent in place. For mechanical engineering, automation, support by geographic information system and artificial intelligence (section 10.2), it remains for forestry to bear the developmental costs that such digitalization entails. Using some of these methods could potentially allow for more precision in forestry management with regard to the forest reproductive material used and the physical location of planted trees.

Figure 22. Thinning corresponds to an area of approximately 300 000 to 350 000 hectares every year. Knowledge is needed on how thinning affects the state of the forest, in particular natural and cultural environmental values. Photo: Erik Rahm, the Swedish Forest Agency.

10.2 Digitalization

In addition to the more traditional technologies utilized in forestry, digitalisation is used at an increasing extent. The Swedish Forest Agency use remote sensing data within several areas, and it is well integrated with other spatial data in the organizations geographical information system (GIS). Currently a new satellite image is available in the GIS over the same area approximately every three days during the most part of the year, except for the darkest winter months.

Since 1999 the Swedish Forest Agency has had a nationwide annual coverage with satellite data and since 2003 change detection of satellite images has been used to map felling on annual basis to monitor and follow up the forest regrowth has been used. Satellite images have also been used to map the extension of storm damaged forest and to send information to affected forest owners.

In recent years, the vitality of many stands of *Picea abies* has decreased, mainly due to drought, and the forests have suffered extensive damage from bark beetle outbreaks. Tools to detect changes in tree vitality using satellite images make it possible to identify dead and weakened trees and identify stands with bark beetle outbreaks, so infested trees can be removed to minimize the impact on the surrounding healthy forest (Figure 23).

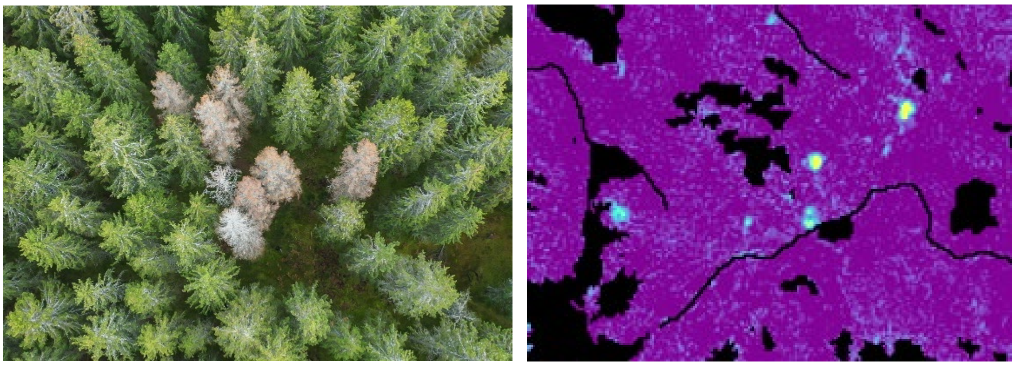

Figure 23. In recent years many stands of *Picea abies* have suffered extensive damage from bark beetle outbreaks, mainly due to drought (photo from drone to the left). Using satellite images (right) make it possible to identify dead and weakened trees and stands, so infested trees can be removed to minimize the impact on the surrounding healthy forest. Photo: Yaman Albolbol (left) and the Swedish Forest Agency, Copernicus data, 2019 (right).

By using artificial intelligence and a combination of geographical data, it is possible to predict where the risk of insect damages is high. This information is available to forest owners through various map services. Moreover, it is possible to detect areas with poor regrowth. The old clear cuts are mapped using change detection in old satellite images.

Since 2015, nationwide forest estimates of wood quality have been available as a raster dataset. The forest estimations are produced using regression analysis with data from airborne laser scanning (LIDAR) and field plots from the National Forest Inventory as ground truth data (Figure 24). The estimated forest variables are mean height, mean stem diameter, basal area, stem volume and biomass. The dataset is a result from a collaboration between the Swedish Forest Agency, the Land Survey and the Swedish University of Agricultural Sciences. The objectives are to increase forest production and enable more efficient environmental considerations in forestry. The data is open for everyone to use free of charge, in order to maximize the benefit to society.

Figure 24. Sweden uses digital techniques to an increasing extent for several purposes in forestry. Image data on: Laser scanning (top left). Photo: the Swedish mapping, cadastral and land registration authority. **Drone (bottom left).** Photo: Adobe stock. **Satellite Sentinel 2A (right).** Photo: European Space Agency. The background image on clouds: Anton Holmström.

A new nationwide laser scanning began 2019. Funding from the government and co-funding from the forest companies has secured nation-wide update every seven years.

Forest estimations from two different times over the same area enables calculations of forest growth on pixel level. The spatial resolution in the new laser scanning data is higher than in the previous data, enabling even better estimates.

Aerial ortho photos are another important data set. In southern Sweden, new images are available every second year and the spatial resolution is 0,16 meters. In the rest of Sweden, the spatial resolution is 0,50 meters and new images are available every 4-6 years.

The use of drones has increased significantly in the recent years and the Swedish Forest Agency has many units distributed among the forest officers in the country. The drones are used as support in field for real-time viewing or mapping over a larger area. The legislation requires that the stored data must be examined by the Swedish Land Survey due to security reasons, which currently limits the potential of the data to a certain degree.

Since 2019, nationwide landcover classification is available for Sweden. The dataset is the result of a collaboration between several Swedish authorities. The estimated raster dataset is based on multiple data set, such as laser scanning (LIDAR), aerial photos and time series of satellite images. The data consists of 25 thematic classes including forest productivity. This dataset is also open and free for the public to use.

In the future, collaborations in the area of digitalization will become more common. It is too expensive for individual organizations to continuously download and host data. The use of co-funded data cubes is most likely to increase. The data cubes have optimized performance and an enormous capacity of storage. All data storage and analyses are conducted in the data cube and the end user can just request what information to be displayed.

In the future, the use of radar data will increase within forest applications. Radar is an active sensor that send out a signal itself and detects the returned reflectance. The large advantage is that the reflectance is not depending on sunlight. Thus, radar data can be very useful during the winter to improve the possibility of mapping storm damaged forests.

10.3 Needs, challenges and opportunities

Adaption to climate change, including measures to prevent outbreaks of pests, is fundamental for a sustainable management of forest genetic resources.

Forestry with *Picea abies* dominates in southern Sweden whereas forestry with *Pinus sylvestris* dominates in northern Sweden. This is partly independent of which tree species that is most suitable for the actual site and is in Sothern Sweden mainly a consequence of the game damage which influence the forest owners´ choice of tree species (section 4.3). *Picea abies* is less susceptible to moose browsing than *Pinus sylvestris*.

The Swedish Government has called for an increased variation in forestry and forest management[124]. It could be argued whether the current trend of reduced natural regeneration and domination of few tree species contributes to this intention. Large forest areas dominated by one tree species that, in many cases, is less suitable for the soil type may have a negative impact on the forest production. This risk exacerbates the problems with game browsing and does not provide a spread of risks in forestry. It can also be negative for social and ecological values of the forests. Natural regeneration can make the regrowth phase more appealing to the public than planting. Moreover, seed trees or shade trees provide a smoother transition between forest generations and offers habitats for species connected to old forests.

A recently published report describes how the Swedish authorities work with climate change adaptation[125]. Based on an analysis of the vulnerability of forests and forestry to climate change, objectives were established, and adaption measures were suggested that largely connect to the sustainable use of forest genetic resources. The work was conducted in a dialog-based manner in order to make the objectives and proposals legitimate among forestry stakeholders. The objectives and measures are to maintain a profitable forestry with an evenly spread wood delivery over time, while avoiding increased negative effects on other societal and environmental values. One objective was: In the long-term,

[124] Bills 1992/93: 226 and 2013/14: 141

[125] Ståhlberg D, Eriksson H, Bergqvist J, Isacsson G & Lomander A. 2020. Adaption of forests and forestry in Sweden to climate change: Objectives and proposals for action. Klimatanpassning av skogen och skogsbruket –mål och förslag på åtgärder. Skogsstyrelsen Rapport 2019/23. In Swedish with an English abstract.

damage is cost effectively counteracted through the formation of site adapted forests with reduced sensitivity for storm-felling and high level of variation. Another objective was: Forestry develops to avoid increasing damage on the environment and other societal values over time.

10.4 Priorities for capacity building and research

The above mentioned report stresses that forest owners by mean of active silvicultural measures can adapt their forests to cope better with the future climate and forest damage. Authorities and research institutions can facilitate adaptive measures in various ways and especially has a responsibility to collect data, monitor, develop and communicate knowledge and advices. During 2020–2024, the Swedish Forest Agency will put efforts to link the adaptation perspective to the wood production perspective in campaigns under the Swedish National Forest Program umbrella and through dialogues with stakeholders.

With increased risk of forest damage, it becomes more important to create forests where the risks are spread in different ways. For instance, the proportion of *Picea abies* could be reduced in wind-exposed parts of the terrain and should preferably decrease in southern Sweden, mainly by management regimes based on site-specific conditions. Increasing the area of deciduous forests and mixed forests with deciduous and coniferous trees reduces the risk of injury in several ways while at the same time promoting biodiversity.

Considering climate change and increasing threats from known and unknown pests, forest owners are recommended to use a variation both in silvicultural measures and forest reproductive material. This can be achieved by regenerating, by planting, sowing and natural regeneration using several tree species and several suitable seed sources. The management system could include both clearcutting and continuous cover forestry to further spread the risks.

Thinning can have substantial effects on the forest environments and on forest genetic resources (section 10.1.2). There is a need to investigate how thinning affects the state of the forest with a particular focus on different natural and cultural environmental values.

The Swedish Forest Agency sends the message to the forest owners that it is in their own interest to adapt their forestry to climate change. The Swedish Forest Agency often links climate adaptation with questions concerning forest damage and production in its external extension activities. In these contexts, the connection to a sustainable use of forest genetic resources should also be highlighted.

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

Part 5: State of capacities and polices

This chapter describes the current state of capacities and polices such as regulations and other instruments related to the conservation, use and development of forest genetic resources in Sweden. Moreover, needs, challenges and opportunities for strengthening the national institutions and policies on forest genetic resources are described.

11.1 National coordination mechanism

The Swedish Forest Agency[126] is the national authority in charge of forest-related issues. It operates directly under the auspices of the Ministry of Enterprise and Innovation . The Swedish Forest Agency has offices in approximately 80 towns in Sweden. This facilitates field-based work, such as surveys, site visits and contacts with forest owners and these activities are largely carried out by employees at the local offices.

The Swedish forest policy places equal emphasis on two main objectives: the production and environmental goals. Also, the value of forests for recreation and outdoor activities is highlighted. The Swedish Forest Agency works to ensure that the country's forests are protected and used in such a way that they yield a good, sustainable return while maintaining biological diversity.

11.2 Institutions and stakeholders

The main stakeholders concerned with and responsible for forest genetic resources are described in earlier sections in this report: *in situ* conservation (section 6.2), *ex situ* conservation (section 7.1), and breeding programs (section 9.2).

The Swedish forest sector in the broad sense consists of a large number of actors and can be described in several ways, for instance:

- Forest owners: Individual owners, private-sector companies, state owned companies, other private owners, other public owners, forest companies and the state;
- Government agencies: Mainly the Swedish Forest Agency, Swedish Environmental Protection Agency, the Swedish Board of Agriculture, the Swedish National Heritage Board, the Swedish Agency for Marine and Water management, the Sami Parliament and local country authorities;
- Non-governmental organizations: For instance, Birdlife Sweden, Nature tourism companies, the Swedish Hunter organization, the Swedish Local Heritage Federation, Swedish Outdoor Association, Swedish Society for

[126] Swedish Forest Agency. About us. https://www.skogsstyrelsen.se/en/about-us/. Downloaded 2020-05-15.

Nature Conservation, the Swedish Sami National Assembly and WWF Sweden;

- Other organizations: for instance, the Federation of Swedish Farmers, industrial forest enterprises, the Swedish union of forestry, wood and graphical workers, the Swedish Association of Forestry Contractors, and the Swedish Forest Industries;

- Universities and research institutions: for instance, the Swedish University of Agricultural Science and the Swedish Forest Research Institute.

11.3 Policy area

The policy area concerning genetic variation began in 1993 with the Convention on Biological Diversity. It laid the foundation for nations to take responsibility themselves to conserve and sustainably use genetic resources. At the 10th convention party meeting in Nagoya 2010, the strategic plan during 2011-2020 for biodiversity was adopted, including the Aichi targets. Several of the goals relate to an improved status for biodiversity by protecting ecosystems, species and genetic variation. In 2014, the Nagoya Protocol came into force and also an EU regulation on measures for user compliance with the Nagoya Protocol[127]. There are also national provisions for users of genetic resources.

The pan-European forest policy process Forest Europe promotes the conservation and sustainably use of forest genetic resources. As a result of a resolution adopted by the first Ministerial Conference of the Forest Europe process, the pan-European cooperation program Euforgen[128] was established in 1994. Euforgen facilitates the cooperation on conservation and sustainable use of forest genetic resources in Europe as an integral part of sustainable forest management. Sweden has participated in Euforgen from the beginning of the program.

Genetic variation of forest trees is also encompassed by the Swedish forest policy environmental objective, stating that "*The natural productive capacity of the forest land must be conserved. Biological diversity and genetic variation in the forest must be ensured. The forests should be used in such a way that plant and animal species that naturally belong in the forest are given conditions to survive under natural conditions and in viable populations* ".

Also, the national environmental quality objective "Sustainable forests" includes provisions on genetic variation. It stipulates that "*Habitats and naturally occurring species associated with forest areas have a favorable conservation status and sufficient genetic variation within and between populations*". A corresponding provision is found in the environmental quality objective "A rich diversity of plant and animal life".

---

[127] Regulation (EU) no 511/2014 of the European parliament and of the council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union.

[128] European Forest Genetic Resources Programme, Euforgen, http://www.euforgen.org/ Downloaded 2020-05-15.

11.4 Regulations

Sweden has, in the Forestry Act, regulations that concern various aspects of forest genetic resources. For instance, it contains specific provisions for regeneration methods, scarification, sowing, planting, management of young forests and other measures to ensure regeneration.

According to the regulations, only forest reproductive material that can enable forest stands to develop in an adequate way for the site conditions should be used. The reproductive material should be able to utilize the forest land in such a way that it can lead to a satisfactory timber production.

When transferring forest reproductive material, consideration should be taken regarding the climatic and other relevant conditions for the forest cultivation. There are regulations concerning both the transfer of *Fagus*, *Betula* and *Quercus*. and the latitudinal origin of *Pinus sylvestris* and *Picea abies* for forest cultivation.

There are also regulations for the use of vegetatively propagated material; maximum five percent of a forestry unit may be cultivated with vegetatively propagated material, however cultivation on a maximum of 20 hectares is always allowed. Moreover, there are regulations concerning the area, geographical distribution and concentration of introduced tree species in Sweden.

According to the Forestry Act, the introduction of new forest reproductive material could be subject to an environmental impact analysis. So far, no such analyses have been carried out for introduced tree species or any other forest reproductive material.

The regulations for forest reproductive material are described in section 8.1.

11.5 Other instruments

11.5.1 Economic incentives

Instruments other than regulations also apply to the use of forest genetic resources in Sweden. For instance, the state can provide economic support for forestry with noble hardwoods. The support intends to compensate forest owners for the higher costs arising from regeneration with noble hardwoods. Support is given to various measures for regeneration, such as scarification, fencing, plants, planting and clearing. Support is prioritized, among other things, for regeneration with deciduous trees.

11.5.2 Policies and strategies

As previously mentioned, the Swedish Forest Agency has a strategy for gene conservation. Forest genetic resources are influenced by a number of related policy areas in Europe and globally (section 11.3)[129]. Sweden does not however have a separate policy or strategy for the national use of forest genetic resources.

[129] Bogataj AZ, Paitaridou P, Olrik DC, Wolter F, Koskela J, Hubert J, Koiv K, Bakkebo Fjellstad K, Rusanen M,Bouillon P, Longauer R, Bordács S, Black-Samuelsson S & Orlovic S. 2015. The implications of global, European and national policies for the conservation and use of forest genetic resources in Europe. EUFORGEN, Bioversity International, Rome, Italy. 42 pp. ISBN 10: 978-92-9255-033-2.

11.5.3 Counselling and advisory services

Since 1993, the governing principle of the Swedish forest policy has been "freedom with responsibility". The forest legislation is relatively open with few detailed regulations. The responsibility for balancing production, environmental and social values in the forest sector is to a large extent a right resting with the forest owner. It is the forest owner who chooses options for forestry action which are based on their goals and within the legal boundaries. However, the forest policy presumes a willingness of forest owners and users to make larger investments in their forest management, both concerning conservation efforts and measures to improve production than what is stipulated by the law. The advisory services from the Swedish Forest Agency should thus provide clear information on the benefits and risks with different forestry options, so that the forest owner or forest entrepreneur are able to make well-informed decisions.

In 2011, representatives from the forest industry's companies and organizations, nature conservation among others joined hands to develop targets for conservation measures in forestry operations[130]. To date, there are around fifty targets that illustrate and document practical experience, knowledge and the latest research findings to guide forest owners, forestry companies and professionals. The targets include aspects of genetic resources to a varying extent. Nevertheless, they are a solid example showing how constructive dialogue and collaboration in the forestry sector has the potential to contribute to the fulfillment of Swedish forest and environmental policy.

11.5.4 Certification

There are two different forest certification systems in Sweden, FSC and PEFC. According to the Swedish PEFC certification[131], approximately 47 000 forest owners and more than 3 300 entrepreneurs are certified in Sweden. The areal of certified forest land is nearly 16 million hectares. According to the Swedish FSC[132], over 12 million hectares of forests in Sweden are FSC-certified. The certified area is distributed among 23 companies, including 13 umbrella organizations that certify smaller landowners. 77 % av the total certified productive forest area is certified in accordance with both FSC and PEFC[133].

The FSC and PEFC certifications also include aspects of forest reproductive material, mainly regarding introduced (exotic) tree species. A new FSC standard will apply from Autumn 2020[134]. Genetic aspects are addressed directly only once, in Article 10.4.1: "*Genetically modified organisms are not used*". Genetic variation is not mentioned specifically, but indirectly embedded when referring to

---

130 Skogsstyrelsen. Målbilder för god miljöhänsyn. https://skogsstyrelsen.se/malbilder. Downloaded 2020-05-15.

131 Svenska PEFC. Skogsstandard. https://pefc.se/skogsstandard/. Downloaded 2020-05-15.

132 FSC. Statistik och fakta. https://se.fsc.org/se-se/fscs-betydelse/statistik-och-fakta. Downloaded 2020-05-15.

133 Eriksson A 2019. Voluntary set-asides and area under forest management certification schemes. Statistical report JO1404 SM 1901. Swedish Forest Agency. In Swedish with an English abstract.

134 The FSC National Forest Stewardship Standard of Sweden. FSC-STD-003-05-2019 V-1. The standard will come into effect during the autumn 2020.

biodiversity, for instance in Article 5.1.1: "*Forest owners aim for methods of silviculture and forest management that generate optimal utilization of the diversity of resources and ecosystem services that the forest can provide*".

The new FSC standard, among other things, also requires an increase of the share proportion of productive forest which is set-aside to nature conservation or managed with long-term protection and enhancement of conservation value and/or social values as the primary objective. Furthermore, explicit requirements have been introduced regarding endangered species and deciduous trees in all parts of the forest management cycle.

11.6 Research and development

The importance of forest genetic resources in research and development includes among other things traditional and biotechnological breeding of forest reproductive material, as well as biotechnological development of for example bark to develop new products from forest raw materials. Below are some examples of the research and development of forest genetic resources in Sweden.

Umeå Plant Science Centre (UPSC) for forest biotechnology[135] is the umbrella for two Swedish universities that conducts research on the mechanisms behind plant development and adaptation to environmental changes. The research disciplines include genetics, ecology, physiology and molecular biology.

Research on forest genetics and tree breeding on conifers is performed at UPSC[136]. The genetic base of genetic variation is analyzed in quantitative traits such as growth, wood quality, phenology and biotic and abiotic resistance. The results can be used to design breeding programs for *Picea abies* and *Pinus sylvestris*. Genotype by environment interactions are studied to describe optimal breeding populations and mating designs that match the environment (breeding zone) to design an optimal breeding strategy. Also, genetic causes of adversely related important breeding traits such as wood quantity versus wood quality are studied. Optimal selection and mating methods are developed to deal with these traits in breeding programs. To improve the efficiency of tree breeding, genetic candidate genes or genome-wide approach are used to understand how DNA variation is associated with phenotypic variation.

At Uppsala university, research is performed on the genetics of climatic adaptation in trees[137]. The aim is to identify the genes that control local adaptation to photoperiod, temperature and growth rhythm in *Picea abies*. Functional studies of candidate genes in *Picea abies* and the model species *Arabidopsis thaliana* are

---

[135] Umeå Plant Science Centre. The UPSC for forest biotechnology. https://www.upsc.se/upsc-centre-for-forest-biotechnology.html. Downloaded 2020-05-08.

[136] Umeå Plant Science Centre. Wu, Harry - Quantitative Genetics and Tree Breeding. https://www.upsc.se/researchers/4657-harry-wu-quantitative-genetics-and-tree-breeding.html Downloaded 2020-05-08.

[137] Uppsala Universitet. Genetics of climatic adaptation in trees. http://www.ieg.uu.se/plant/lagercrantz-group/ongoing-research/#gocait. Downloaded 2020-05-08.

combined with association mapping and population genetic analysis of the same genes in *Picea abies*.

The Swedish University of Agricultural Sciences (SLU) performs research on several aspects of forest genetic resources[138]. One research group studies the genetic involvement in local adaptation in e.g. phenology in e.g. *Picea abies* and *Populus tremula*[139]. The research also includes assessments of how genetic variation is shaped by natural selection and other evolutionary processes.

SLU, Umeå University and the Forestry Research Institute of Sweden (Skogforsk) are also responsible for Future Forests[140], an interdisciplinary forest research platform that integrates different scientific fields and increases the collaboration between researchers and society.

The Forest Research Institute of Sweden, Skogforsk is a research body for the Swedish forestry sector. The research is applied and demand-driven and covers various fields. The research areas that most clearly affects forest genetic resources are forest tree breeding (see chapter 9), forest damage and seedling production.

Skogforsk´s research on forest damage include damage caused by browsing wildlife, harmful fungi and insects. It develops methods for preventing insect damage in seed nurseries, monitoring and studying the spread of infection by rust fungus and to improve genetic breeding of *Fraxinus exelsior* in Sweden to increase resistance to ash dieback. The research and development of seedling production encompass methods for treating seeds and cultivating plants and offer an advisory service about seeds and plants.

There are also several other research platforms concerning for instance genomic selection in *Picea abies*[141] and Trees for the future (T4F)[142].

Some examples of research on various aspects of genetic variation in forest trees are also described in section 5.3.

[138] SLU. Research at SLU. https://www.slu.se/en/research/. Downloaded 202-05-08.

[139] Ingvarsson lab. Plant genomics and plant breeding. http://www.pkilab.org/wp/. Downloaded 202-05-08.

[140] SLU. Future Forests. https://www.slu.se/en/Collaborative-Centres-and-Projects/future-forests/. Downloaded 202-05-08.

[141] Umeå Plant Science Centre. Genomic selection in Norway spruce, https://www.upsc.se/organization-gsns.html. Downloaded 202-05-08.

[142] SLU. Trees for the future, T4F. https://www.slu.se/en/Collaborative-Centres-and-Projects/trees-and-crops-for-the-future/t4f/. Downloaded 202-05-08.

11.6.1 Donors of research grants

There are several donors of research grants for forest genetics, mainly Skogssällskapet[143], Föreningen Skogsträdsförädling[144] and The Swedish Research Council Formas[145]. SNS Nordic Forest research[146] promotes Nordic research cooperation for sustainable forestry. There are scholarships supporting education and knowledge exchange concerning production of forest reproductive material, regeneration methods and forest tree breeding in the Nordic countries.

11.7 State of education and training

In 2013, an industrial graduate student research school of forest genetics, biotechnology and breeding was launched[147]. It is a collaboration between academia and industry and is currently running its third class with postgraduate students. Areas of study include molecular genetics of prioritized traits, genomics, technology for somatic embryogenesis, statistics, quantitative genetics and breeding theory. Altogether 26 students are involved in the research school.

Forest genetics and forest tree breeding are covered in courses within the forestry program[148] (Figure 25). One objective is that students, after completing the course, should be able to explain how forest tree breeding, production, storage and distribution of forest reproductive material are carried out in practice. In the program for foresters, the concept of quantitative genetics and how genetic methods and forest management can interact in modern forestry are introduced[149]. Moreover, forest biotechnology and new molecular biological methods are included, such as the gene scissors CRISPR-cas and marker assisted selection, and how they can be used in forest tree breeding.

At the master's level, the course in biology and biotechnology for forestry production systems goes more in depth and treats specific topics such as genetic variation, genomic selection, genetic techniques such as genome wide association studies and phenotype characterization. Strategies for collection of genetic data and statistical analysis are also evaluated. Also, the knowledge about eco physiological processes is deepened and how tree growth and forest health are dependent on the genetic set-up, population history and external factors.

There are also master’s programmes in plant biology for sustainable production that specialize in forest biotechnology and in plant and forest biotechnology.

---

[143] Skogssällskapet. Forskning. https://www.skogssallskapet.se/forskning.html. Downloaded 2020-05-08.

[144] Föreningen skogsträdsförädling. http://skogstradsforadling.se/. Downloaded 2020-05-08.

[145] FORMAS. Knowledge for a sustainable transformation. https://formas.se/en/start-page.html. Downloaded 2020-05-08.

[146] SNS Nordic Forest Resarch. https://nordicforestresearch.org/. Downloaded 2020-05-08.

[147] Forskarskolan bioteknik, skogsgenetik förädling. Research school in forest genetics, biotechnology and breeding. http://resschool.slu.se/. Downloaded 2020-05-08.

[148] Daniel Gräns, Senior Lecturer, Ph.D, Swedish University of Agricultural Sciences. Mail correspondence, November 30, 2019.

[149] Ola Carlén, PSR jägmästarprogrammet, personal communication. 2019-10-14.

Figure 25. Students at the Swedish University of Agricultural Science SLU: A break at campus (left) and a lesson in the field (right). Photos: Jenny Svennås Gillner, SLU (left) and Nils Blomqvist, SLU (right).

11.8 Needs, challenges and opportunities

Generally, the conservation and sustainable use of forest genetic resources is treated to a very limited extent within national policies, certification systems, strategies and forestry programs. Consequently, there are several needs and challenges, but also opportunities for strengthening the national institutional framework on forest genetic resources.

Among forest stakeholders, the interest in forest gene conservation is in general limited and mainly concerns the major tree species in breeding programs. It is motivated to address *in situ* (and *ex situ*) conservation of forest genetic resources more specifically and implement this in national forest policies. Currently genetic variation only falls in under the broader issue of biodiversity conservation.

Other needs concern the limited regulation concerning forest genetic resources. Existing legislation mainly applies to the marketing of forest reproductive material. For the few other regulated areas, such as the proper transfer of forest reproductive material, surveillance is hardly possible as the identity of the material is not documented during regeneration. This calls for the development of an appropriate method to document plant identity (section 8.6.1).

11.9 Priorities for capacity-building

There is a general need both to integrate forest genetic resources into other relevant areas and to make the topic more visible (section 1.4). There are significant and close connections between the areas of genetic resources, climate change and biodiversity, among others. The adaptation of populations and species to environmental changes are dependent on genetic variation in adaptive traits.

It is crucial to raise the awareness among relevant authorities, organizations and forest owners concerning the conservation and sustainable use of forest genetic resources. Several measures and communication channels are needed. One example is to develop policies in areas such as regeneration, clearing and thinning. The Swedish Forest Agency has recently initiated work in this area. Another example is to address the research needs of various aspects of forest genetic resources to universities and research institutions (sections 8.6.2, 9.4 and 10.4).

12 Cooperation on forest genetic resources

This chapter describes Sweden's involvement in international and national cooperation on forest genetic resources. It explains how Sweden has benefited from and contributed to the international cooperation. Also, needs, challenges and opportunities for strengthening cooperation are identified.

12.1 International cooperation

Some examples are presented below of international and regional cooperation in forest genetic resources that Sweden is or has been involved in since 2013.

Nordgen Forest[150] is a Nordic body and meeting place for questions concerning conservation and sustainable use of forest genetic resources. Nordgen Forest consists of a working group on forest genetic resources and a forest regeneration council, both with representatives from all Nordic countries. Nordgen Forest is a forum for researchers, practitioners and managers and arrange thematic days and conferences. Moreover, Sweden has been a member of the European Forest Genetic Resources Programme, Euforgen (section 11.3) from 1994.

Within the EU and with OECD, there is cooperation and a continuous harmonization of regulations and definitions concerning the production and trade of forest reproductive material.

International research cooperation in forest genetic is generally good. One example is the European project GENTREE[151]. Cooperation with one or a few countries in smaller research studies is also common in forest genetic resources.

12.2 Benefits and contributions to international cooperation

Sweden benefits in several ways from international cooperation. One example is the advice and support from Euforgen that facilitated the development of *in situ* gene conservation of forest trees (sections 6.1-2). Regional advice will also support the Swedish Forest Agency to develop national policies for a sustainable management of forest genetic resources, within management stages such as forest regeneration, clearing and thinning. The idea is to implement and communicate these policies to enable a more sustainable use of forest genetic resources through, for example, advisory services to forest owners.

The need of regional cooperation will become increasingly important as aspects of forest genetic resources are integrated into several areas at the EU, European and global levels. This applies for instance to adaptation to climate change and outbreaks of insects and pests, where Sweden will become increasingly dependent on knowledge transfer from southern countries.

---

[150] NordGen. About NordGen Forest, https://www.nordgen.org/en/forest/. Downloaded 2020-05-08.

[151] GENTREE, Optimizing the management and sustainable use of forest genetic resources in Europe, http://www.gentree-h2020.eu/. Downloaded 2020-05-08.

In the spirit of the national forest program, Sweden has the ambition to share experiences and knowledge internationally at a greater extent. Sweden is a large forest country involved in various international forest policy processes and collaborative groups that are valuable channels for Sweden to raise and retrieve knowledge and experiences concerning current issues on forest genetic resources.

In general, international cooperation especially in research include mutually beneficial exchange such as access to expertise and international funds and larger networks of knowledge. This increases reach and impact of the research. International teams also bring together different methodological approaches and cultural aspects that widen the perspectives of analysis and interpretation.

12.3 National cooperation

The national cooperation between Swedish authorities concerning genetic resources is currently relatively limited. There is a need to increase cooperation on monitoring and conservation of forest genetic resources.

As regards genetic monitoring, even though applicable methods are similar, the characteristics of forest trees differ significantly from other plant species and the forestry conditions are also very different from agriculture. Forest trees have much longer rotation times and their levels of inter- and intrapopulation genetic variation are often high as compared to other plant species. In addition, especially wind pollinated tree species such as *Picea abies*, *Pinus sylvestris* and *Betula* spp. have extensive gene flow by pollen and seeds at the same time as the possibilities to control the gene flow are almost non-existent. Forestry covers immensely larger and more heterogenous areas than agriculture. These aspects explain why a common useful system for monitoring genetic variation in forest trees and other plant species would likely be challenging to develop.

12.4 Needs, challenges and opportunities

International cooperation in research, breeding and gene conservation on forest genetic resources is adequate and well-functioning. What seems more relevant to develop is national collaboration on gene conservation and genetic monitoring.

Regarding gene conservation, large forests that are permanently protected such as nature reserves potentially offer excellent opportunities for *in situ* conservation of plant and forest genetic resources. The conditions concerning legislation, employee training and customization of IT systems need to be properly analyzed and in place before this gene conservation can be realized.

A clear prerequisite in order to perform any genetic monitoring of prioritized tree species is additional financial and human resources. Universities or research institutes with experience of environmental monitoring and with necessary equipment are likely the most suitable part to take responsibility for planning, executing and analyzing data from genetic monitoring. Appropriate methods for each aspect of the monitoring process need to be developed and additional resources are needed before genetic monitoring in forest trees becomes reality.

13 Recommended actions for the future

Part 6: Challenges and opportunities

This chapter summarizes the recommendations for further actions to strengthen the conservation, use and institutional framework of forest genetic resources in Sweden. The recommendations are based on some of the challenges and opportunities for forest genetic resources presented in the earlier chapters.

13.1 Value and importance of forest genetic resources

The Agenda 2030 goals that concern forests and forestry are seldom treated from the perspective of forest genetic resources. While aspects of biodiversity conservation and the need of forests and forestry to adapt to climate change remain of vital importance, the awareness of forest genetic resources and their significance for the Swedish forests and forestry needs to increase. Forest genetic resources must therefore be addressed more systematically and become properly integrated in future strategies for biodiversity conservation and sustainable forest management.

13.2 State of forests

Previous assessments have revealed an inadequate status of several forest ecosystem services in Sweden. This calls for in-depth analyses to clarify which factors influence these ecosystem services and to reveal the instruments and measures that are most suitable for improving their status. The focus initially could be to analyse a few ecosystem services and in parallel perform broad socio-economic analyses.

13.3 State of other wooded lands

Other wooded land is not exploited in forestry or in other human activities in Sweden. Hence, they are also paid less interest regarding monitoring and research and therefore compared to forest land there is less knowledge about other wooded land. More attention should be payed to other wooded land in research and monitoring due to their importance for genetic resources, biodiversity and mitigation to climate change.

13.4 State of diversity within forest trees

Biodiversity comprises several levels, from genetic variation to species and ecosystem diversity. Genotypes and gene variants (alleles) with an actual or potential value for the economy, environment, science and society are largely unknown. Therefore, there are reasons to both conserve genetic variation and to sustainably utilize it. The Swedish Forest Agency should more systematically promote research needs to the government, universities and research institutions, primarily concerning the use (section 8.6.2), breeding (section 9.4) and management (section 10.4) of forest genetic resources.

13.5 *In situ* conservation

It is important to secure resources for nature conservation management in the habitat protected areas that house gene conservation units in Sweden.

13.6 Use of forest genetic resources

There is a need to develop a reliable and well-functioning system that documents the forest reproductive material used in forestry. Today there is no such system. Such system would provide information on possible genetic causes to certain forest damage, the areas that are cultivated with genetically improved material, from which breeding cycle the material is derived or the share of naturally regenerated trees within planted forests. Information on the plant identity allows the forest reproductive material to be evaluated both in terms of production and environmental aspects, which is of great value for forest owners, tree breeders, researchers and authorities.

13.7 Genetic improvement and tree breeding

The lack of breeding programs and seed supply for many tree species, except for *Pinus sylvestris* and *Picea abies*, make it difficult for forest owners to adapt the choice of forest reproductive material to climate change. Hence, different types of breeding programs for additional tree species needs to be developed.

Genetic variation in resistance provides the opportunity to breed for individuals with low susceptibility to certain pests. It is important to work more actively with the issue of resistance in breeding programs and to try to ensure that genes of importance for resistance to existing and new problematic pests are identified and maintained as far as possible.

13.8 Forest management

It is the responsibility and interest of the forest owners to, by mean of active silvicultural measures, adapt their forests to better cope with the future climate and forest damage. Authorities and research institutions can facilitate adaptive measures in various ways and especially have a responsibility to collect data, monitor change and to develop and communicate knowledge and best practice.

A general recommendation to forest owners is to use a variation both in silvicultural measures and forest reproductive material. This can be achieved by planting, sowing and natural regeneration with several tree species and using several suitable seed sources. The management system could include both clearcutting and continuous cover forestry to further spread the risks.

With increased risk of forest damage, it becomes more important to create forests where the risks are spread in different ways. For instance, the proportion of *Picea abies* could be reduced in wind-exposed parts of the terrain and should preferably decrease in Southern Sweden, primarily by management regimes based on site-specific conditions. Increasing the area of deciduous forests and mixed forests with deciduous and coniferous trees reduces the risk of damage in several ways while at the same time promoting biodiversity.

Thinning can have substantial effects on the forest environments and on forest genetic resources. An investigation is needed to clarify how thinning affects the state of the forest with a particular focus on different natural and cultural environmental values.

The Swedish Forest Agency sends the message to the forest owners that it is in their own interest to adapt their forestry to climate change. The Swedish Forest Agency often links climate adaptation with questions concerning forest damage and production in its activities for foresters and forest owners. In these contexts, the connection to a sustainable use of forest genetic resources should also be highlighted.

13.9 Institutional framework

There is a general need both to integrate forest genetic resources into other relevant areas and to make them more visible. Several aspects of conservation and sustainable use and management of forest genetic resources connect strongly with issues such as climate change and biodiversity. Genetic variation is a prerequisite for the adaptation of populations and species to environmental changes. Therefore, it is crucial to raise the awareness among relevant authorities, organizations and forest owners concerning the conservation and sustainable use of forest genetic resources. Several measures and communication channels are needed. One example is to develop policies in areas such as the silvicultural aspects of regeneration, clearing and thinning. The Swedish Forest Agency has recently initiated work in this area.

13.10 International and national cooperation

National collaboration concerning gene conservation and genetic monitoring is required for forest genetic resources. Regarding gene conservation, large forests that are permanently protected, such as nature reserves, potentially offer excellent opportunities for *in situ* conservation of plant and forest genetic resources. The conditions concerning legislation, employee training and customization of IT systems need to be properly analyzed and in place before gene conservation can be realized.

A clear prerequisite in order to perform any genetic monitoring of prioritized tree species is additional financial and human resources. Universities or research institutes with experience of environmental monitoring and with necessary equipment are likely the most suitable part to take responsibility for planning, executing and analyzing data from genetic monitoring. Appropriate methods for each aspect of the monitoring process needs to be developed and additional resources are needed before genetic monitoring in forest trees becomes reality.

14 References

Andersson C, Blombäck P, Bondeson L, Celander T & Lundblad J. 2016. Agenda 2030 – underlag för genomförande. Skogsstyrelsen Meddelande 8, 2016. In Swedish.

Andersson C, Andersson E, Blomqvist S, Eriksson A, Eriksson H, Karlsson S & Roberge J-M. 2019. Fördjupad utvärdering av Levande skogar 2019. Skogsstyrelsen Rapport 2019/2. In Swedish.

Androsiuk P, Shimono A, Westin J, Lindgren D, Fries A & Wang X-R. 2013. Genetic status of Norway spruce (*Picea abies*) breeding populations for northern Sweden. Silvae Genetica 62:127–136.

Bergquist J, Kalén C & Karlsson S. 2019. Skogsstyrelsen Rapport 2019/16. Skogsbrukets kostnader för viltskador. Återrapportering till regeringen. In Swedish.

Berlin M E, Persson T, Jansson G, Haapanen M, Ruotsalainen S, Bärring L & Andersson Gull B. 2016. Scots pine transfer effect models for growth and survival in Sweden and Finland. Silva Fennica 50. Article id 1562.

Bernhardsson C, Vidalis A, Wang X, Scofield DG, Schiffthaler B, Baison J, Street NR, Rosario García-Gil M & Ingvarsson PK. 2019. An Ultra-Dense Haploid Genetic Map for Evaluating the Highly Fragmented Genome Assembly of Norway Spruce *(Picea abies*). G3: Genes, Genomes, Genetics 9:1623-1632.

Black-Samuelsson S. 2013. The state of the world´s forest genetic resources. Country report Sweden. In English with a Swedish abstract.

Black-Samuelsson S. 2019. Den skogliga genbanken – från storhetstid till framtid. Skogsstyrelsen Rapport 2019/3. In Swedish with an English abstract.

Black-Samuelsson S, Bergqvist J & Uggla C. 2017. Skogsträdens genetiska mångfald, status och åtgärdsbehov. Skogsstyrelsen Rapport 2017/7. In Swedish with an English abstract.

Bogataj AZ, Paitaridou P, Olrik DC, Wolter F, Koskela J, Hubert J, Koiv K, Bakkebo Fjellstad K, Rusanen M,Bouillon P, Longauer R, Bordács S, Black-Samuelsson S & Orlovic S. 2015. The implications of global, European and national policies for the conservation and use of forest genetic resources in Europe. EUFORGEN, Bioversity International, Rome, Italy. 42 pp. ISBN 10: 978-92-9255-033-2.

Brodde L, Adamson K, Camarero JJ, Castaño C, Drenkhan R, Lehtijärvi A, Luchi N, Migliorini D, Sánchez-Miranda A, Stenlid J, Özdag˘ S & Oliva J. 2019. *Diplodia* tip blight on its way to the north: drivers of disease emergence in Northern Europe. Frontiers in plant sciences. doi: 10.3389/fpls.2018.01818.

Chen J, Li L, Milesi P, Jansson G, Berlin M, Karlsson B, Aleksic J, Vendramin GG & Lascoux M. 2019. Genomic data provide new insights on the demographic history and the extent of recent material transfers in Norway spruce. Evolutionary Applications 12:1539–1551.

Christiansen L. 2018. Strukturstatistik. Statistik om skogsägande 2017. Skogsstyrelsen Rapport 2018/12. In Swedish with an English abstract.

Commission on Genetic Resources for Food and Agriculture. 2014a. The State of the World's Forest Genetic Resources.

Commission on Genetic Resources for Food and Agriculture. 2014b. Global plan of action for the conservation, sustainable use and development of forest genetic resources.

de Vries SMG, Alan M, Bozzano M, Burianek V, Collin E, Cottrell J, Ivankovic M, Kelleher CT, Koskela J, Rotach P, Vietto L & Yrjänä L. 2015. Pan-European strategy for genetic conservation of forest trees and establishment of a core network of dynamic conservation units. European Forest Genetic Resources Programme (EUFORGEN), Bioversity International, Rome, Italy.

Eide W *et al.* (red.) 2020. Tillstånd och trender för arter och deras livsmiljöer – rödlistade arter i Sverige 2020. SLU Artdatabanken rapporterar 24. SLU Artdatabanken, Uppsala. In Swedish with an English abstract.

Ekberg K. 2019. Gross felling in 2017 and preliminary statistics for 2018. Statistical report JO0312 SM 1901. Swedish Forest Agency. In Swedish with an English abstract.

Ekberg K. 2019b. Notified areas of final felling in 2019. Statistiskt meddelande JO0314 SM 2001. Swedish Forest Agency. In Swedish with an English abstract.

Eriksson A. 2019. Voluntary set-asides and area under forest management certification schemes. Swedish Forest Agency JO1404 SM 1901.

Eriksson H, Bergqvist J, Hazell P, Isacsson G, Lomander A & Black-Samuelsson S. 2016. Skogsstyrelsen Rapport 2/2016. Effekter av klimatförändringar på skogen och behov av anpassning i skogsbruket. In Swedish.

European Atlas of Forest Tree Species, European commission 2016. On-line version. ISBN 978-92-79-52833-0. DOI 10.2788/038466. Catalogue number LB-04-14-282-EN-N.

Fady B, Aravanopoulos FA, Alizoti P, Mátyás C, von Wühlisch G, Westergren M, Belletti P, Cvjetkovic B, Ducci F, Huber G, Kelleher CT, Khaldi A, Bou Dagher Kharrat M, Kraigher H, Kramer K, Mühlethaler U, Peric S, Perry A, Rousi M, Sbay H, Stojnic S, Tijardovic M, Tsvetkov I, Varela MC, Vendramin GG & Zlatanov T. 2016. Evolution-based approach needed for the conservation and silviculture of peripheral forest tree populations. Forest Ecology and Management 375: 66–75.

Felton A, Löfroth T, Angelstam P, Gustafsson L, Hjältén J, Felton AM, Simonsson P, Dahlberg A, Lindbladh M, Svensson J, Nilsson U, Lodin I, Hedwall PO, Sténs A, Lämås T, Brunet J, Kalén C, Kriström B, Gemmel P, Ranius T. 2019. Keeping pace with forestry: Multi-scale conservation in a changing production forest matrix. Ambio.

Forest statistics 2019. Official Statistics of Sweden. Swedish University of Agricultural Sciences

Frank A & Bergquist J. 2004. Naturskydd och skogligt genbevarande. Skogsstyrelsen, Rapport 11, 2004. In Swedish.

Friis Proschowsky G, Rusanen M, Tollefsrud MM, Sigurgeirsson A, Kroon J, Black-Samuelsson S, Bakkebø Fjellstad K, Solvin T & Hagalid B. 2020. Genetic conservation of forest trees in the Nordic countries. NordGen publication series: 2020:1.

The FSC National Forest Stewardship Standard of Sweden. FSC-STD-003-05-2019 V-1.

Funda T, Wennström U, Almqvist C, Torimaru T, Andersson Gull B & Wang X-R. 2015. Low rates of pollen contamination in a Scots pine seed orchard in Sweden: the exception or the norm? Scandinavian Journal of Forest Research 30: 573-586.

Fussi B, Westergren M, Aravanopoulos F, Baier R, Kavaliauskas D, Finzgar D, Alizoti P, Bozic G, Avramidou E, Konnert M & Kraigher H. 2016. Forest genetic monitoring: an overview of concepts and definitions. Environtal Monitoring and Assessment 88: 493.

Hultberg T, Sandström J, Felton A, Öhman K, Rönnberg J, Witzell J & Cleary M. 2020. Ash dieback risks an extinction cascade. Biological Conservation 244 (2020).

Jansen S, Konrad H & Geburek T. 2019. Crossing borders – European forest reproductive material moving in trade. Journal of environmental management 233: 308-320.

Karlsson L, Fries C, Granath-Limstrand P, Isacsson G, Rydberg D, Samuelsson H & Bertilsson A. 2012. Beredskap vid skador på skog. Skogsstyrelsen. Meddelande 3, 2012. In Swedish.

Kullman L. 1998. Tree-limits and Montane Forests in the Swedish Scandes: Sensitive Biomonitors of Climate Change and Variability: Ambio 27: 312-321.

Laikre L, Larsson LC, Palmé A, Charlier J, Josefsson M & Ryman N. 2008. Potentials for monitoring gene level biodiversity: using Sweden as an example. Biodiversity Conservation 17: 893–910.

Lehmann P, Ammunét T, Barton M, Battisti A, Eigenbrode SD, Uhd Jepsen J, Kalinkat G, Neuvonen S, Niemelä P, Terblanche JS, Økland B & Björkman C. 2020. Complex responses of global insect pests to climate warming. Front Ecol Environ 2020; doi: 10.1002/fee.2160.

Lin Y-C, Wang J, Delhomme N, Schiffthaler B, Sundström G, Zuccolo A, Nystedt B, Hvidsten TR, de la Torre A, Cossu RM, Hoeppner MP, Lantz H, Scofield DG, Zamani N, Johansson A, Mannapperuma C, Robinson KM, Mähler N, Leitch IJ, Pellicer J, Park E-J, Van Montagu M, Van de Peer Y, Grabherr M, Jansson S, Ingvarsson PK & Street NR. 2018. Functional and evolutionary genomic inferences in *Populus* through genome and population sequencing of American and European aspen. PNAS vol. 115 (46).

Metzger MJ, Bunce RGH, Jongman RHG, Sayre R, Trabucco A & Zomer R. 2013. A high-resolution bioclimate map of the world: a unifying framework for global biodiversity research and monitoring. Global Ecology and Biogeography 22: 630–638.

Myking T, Rusanen M, Steffenrem A, Kjaer ED & Jansson G. 2016. Historic transfer of forest reproductive material in the Nordic region: drivers, scale and implications. Forestry 89: 325–337.

Naturvårdsverket 2019a. Uppföljning av målen för friluftspolitiken 2019. Rapport 6904. In Swedish.

Naturvårdsverket 2019b. National Inventory Report Sweden 2019. Greenhouse Gas Emission Inventories 1990-2017 Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

Naturvårdsverket. 2019c. Grön infrastruktur i skogen. Så kan du bidra. 2019. ISBN: 978-91-620-8833-0. In Swedish.

Naturvårdsverket och Skogsstyrelsen. 2017. Nationell strategi för formellt skydd av skog. Reviderad version 2017. In Swedish.

Normark E. 2019. Multiskadad ungskog i Västerbottens och Norrbottens län. Möjliga åtgärder för att mildra problemen. Skogsstyrelsen Rapport 2019/10. In Swedish with an English abstract.

Nystedt B, Street NR, Wetterbom A, Zuccolo A, Lin YC, Scofield DG, Vezzi F, Delhomme N, Giacomello S, Alexeyenko A, Vicedomini R, Sahlin K, Sherwood E, Elfstrand M, Gramzow L, Holmberg K, Hällman J, Keech O, Klasson L, Koriabine M, Kucukoglu M, Käller M, Luthman J, Lysholm F, Niittylä T, Olson A, Rilakovic N, Ritland C, Rosselló JA, Sena J, Svensson T, Talavera-López C, Theißen G, Tuominen H, Vanneste K, Wu ZQ, Zhang B, Zerbe P, Arvestad L, Bhalerao R, Bohlmann J, Bousquet J, Garcia Gil R, Hvidsten TR, de Jong P, MacKay J, Morgante M, Ritland K, Sundberg B, Thompson SL, Van de Peer Y, Andersson B, Nilsson O, Ingvarsson PK, Lundeberg J & Jansson S. 2013. The Norway spruce genome sequence and conifer genome evolution. Nature. May 30; 497:579-584. doi: 10.1038/nature12211.

Payn T, Carnus JM, Freer-Smith P, Kimberley M, Kollert W, Liu S, Orazio C, Rodriguez L, Neves Silva L & Wingfield MJ. 2015. Changes in planted forests and future global implications. Forest Ecology and Management 352: 57–67.

Pettersson J, Andersson C, Ederlöf E & Fabricius Strömbäck A. 2018. Skogens ekosystemtjänster – status och påverkan. Swedish Forest Agency. Report 2017/13. In Swedish with an English abstract.

Posledovich D, Ekblom R & Laikre L. 2020. Mapping and monitoring genetic diversity in Sweden – suggestion for program to start 2020. Manuscript.

Redondo MA. 2018. Invasion biology of forest *Phytophthora* species in Sweden. Doctoral thesis Acta Universitatis Agriculturae Sueciae, 1652–6880. Sveriges lantbruksuniversitet 2018:22. Uppsala, Sweden. ISBN 978-91-7760-184-5. eISBN 978-91-7760-185-2.

Rosvall O & Stener LG. 2013. Förvaltning av lövträdens genresurs - anpassning till förändrat klimat och behov Arbetsrapport. Skogforsk. In Swedish.

Rosvall O, Andersson Gull B, Berlin M, Högberg K-A, Stener L-G, Jansson G, Almqvist A & Westin J. 2016. Skogsskötselserien nr 19, Skogsträdsförädling. Skogsstyrelsen. In Swedish.

Rosvall O, Bradshaw RHW, Egertsdotter U, Ingvarsson PK & Wu H. 2019. Using Norway spruce clones in Swedish forestry: introduction. Scandinavian Journal of Forest Research. 34: 333–335.

Rosvall O, Bradshaw RHW, Egertsdotter U, Ingvarsson PK, Mullin TJ & Wu H. 2019. Using Norway spruce clones in Swedish forestry: implications of clones for management, Scandinavian Journal of Forest Research, 34:5, 390-404, DOI: 10.1080/02827581.2019.1590631.

Skogsstyrelsen, Naturvårdsverket, Statistiska Centralbyrån & Sveriges Lantbruksuniversitet. 2019. Statistik om formellt skyddad skogsmark, frivilliga avsättningar, hänsynsytor samt improduktiv skogsmark. Skogsstyrelsen Rapport 2019/18. In Swedish.

Sønstebø JH, Tollefsrud MM, Myking T, Steffenrem A, Nilsen AE, Edvardsen ØM, Johnskås OR & El-Kassaby YA. 2018. Genetic diversity of Norway spruce (*Picea abies* (L.) Karst.) seed orchard crops: Effects of number of parents, seed year, and pollen contamination. Forest Ecology and Management 411: 132–141.

Statens Energimyndighet. 2019. Energiindikatorer 2019. Uppföljning av Sveriges Energipolitiska mål. Rapport ER 2019:11.

Statistics Sweden 2019. Formally protected forest land, voluntary set-asides, consideration patches and unproductive forest land. MI 41 SM 1902. Statistics Sweden. In Swedish with an English abstract.

Statistics Sweden, Implementation of the 2030 Agenda in Sweden Statistical Review 2019.

Statistics Sweden and Swedish Environmental Protection Agency. 2019. Protected Nature 2018. MI 41 SM 1901.

Statistics Sweden. 2020. Foreign Trade – Exports and imports of goods January – December 2019. HA 22 SM 2001.

Stener L-G. 2012. Clonal differences in susceptibility to the dieback of *Fraxinus excelsior* in southern Sweden. Scandinavian Journal of Forest Research 28: 205-216.

Strand M, Aronsson M & Svensson M. 2018. Klassificering av främmande arters effekter på biologisk mångfald i Sverige – ArtDatabankens risklista. ArtDatabanken Rapporterar 21. ArtDatabanken SLU, Uppsala. ISSN: 1402-6090. In Swedish with an English abstract.

Ståhlberg D, Eriksson H, Bergqvist J, Isacsson G & Lomander A. 2020. Adaption of forests and forestry in Sweden to climate change: Objectives and proposals for action. Klimatanpassning av skogen och skogsbruket –mål och förslag på åtgärder. Skogsstyrelsen Rapport 2019/23. In Swedish with an English abstract.

Sundberg S, Carlberg T, Sandström J. & Thor G. 2019. Värdväxters betydelse för andra organismer – med fokus på vedartade värdväxter. ArtDatabanken Rapporterar 22. ArtDatabanken SLU, Uppsala. In Swedish with an English abstract.

SLU Artdatabanken. 2020. Rödlistade arter i Sverige 2020. SLU, Uppsala. In Swedish with an English summary.

Svenska PEFC ek för 2017. Svenska PEFC:s Skogsstandard. PEFC SWE 002:4.

Svensson L. 2019. Quality of Regrowth 2018/2019. Statistical report JO0311 SM 1901. Swedish Forest Agency. In Swedish with an English abstract.

Swedish Forest Agency 2019a. Sweden Country report on Joint Forest Europe/UNECE/FAO Questionnaire on Pan-European Indicators for Sustainable Forest Management.

Swedish Forest Agency. 2019b. Market Statement 2019 – SWEDEN. UNECE Timber Committee Market Discussion 4-8 November 2019 Geneva, Switzerland.

Swedish Species Information Center, Swedish University of Agricultural science. 2019. The conservation status of the forest habitat types 9010-91F0 under the Habitats Directive 92/43/EEC in Sweden. SLU.dha.2019.5.2-16.

The FSC National Forest Stewardship Standard of Sweden. 2019. FSC-STD-003-05-2019 V-1

Tsuda Y, Semerikov V, Sebastiani F, Vendramin GG & Lascoux M. 2017. Multispecies genetic structure and hybridization in the *Betula* genus across Eurasia. Molecular Ecology 26: 589-605.

UNECE/FAO. 2016. Pilot project on the System for the Evaluation of the Management of Forests (SEMAFOR). Geneva Timber and Forest Discussion Paper 66.

Wang J, Ding J, Tan B, Robinson KM, Michelson IH, Johansson A, Nystedt B, Scofiels DG, Nilsson O, Jansson S, Street NR & Ingvarsson PK. 2018. A major locus controls local adaptation and adaptive life history variation in a perennial plant. Genome Biology volume 19, 72.

Östberg K. 2020. Production of seedlings 2019. Statistical report JO0313 SM 2001. In Swedish with an English abstract.

Internet sources in the order they appear in the text

Swedish forest industries. Forest industry significance. https://www.forestindustries.se/forest-industry/swedish-forest-industry/. Downloaded 2020-05-08.

Food and Agricultural Organization of the United Nations. www.fao.org/forestry/fgr/en/. Downloaded 2020-05-08.

Government Offices of Sweden. Fact sheet: Sweden's National Forest Programme. https://www.government.se/information-material/2019/01/fact-sheet-swedens-national-forest-programme/. Downloaded 2020-05-08.

Skogsstyrelsen. Äbin och andra skogliga betesinventeringar (Updated 2020-05-05). https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/abin-och-andra-skogliga-betesinventeringar/. Downloaded 2020-05-08.

Artfakta SLU Artdatabanken. Naverlönn *Acer campestre*. https://artfakta.se/artbestamning/taxon/5.Downloaded 2020-05-13.

Artfakta SLU Artdatabanken. Sweden. Bohuslind *Tilia platyphyllos*. https://artfakta.se/artbestamning/taxon/1563. Downloaded 2020-05-13.

Artfakta SLU Artdatabanken. Vresalm *Ulmus laevis*. https://artfakta.se/artbestamning/taxon/ulmus-laevis-1628. Downloaded 2020-05-13.

Skogsstyrelsen Swedish Forest Agency. Life ELMIAS. https://skogsstyrelsen.se/en/lifeelmias/. Downloaded 2020-05-13.

https://www.skogsstyrelsen.se/globalassets/projektwebbplatser/life-elmias/rapporter/lifeelmias-final-report.pdf. Downloaded 2020-05-13.

Naturhistoriska Riksmuseet. Den virtuella floran. http://linnaeus.nrm.se/flora/welcome.html. Downloaded 2020-05-13.

EUFORGEN, European Forest Genetic Resources Programme. http://www.euforgen.org/. Downloaded 2020-05-13.

Swedish Environmental Protection Agency. The environmental objectives system. Updated 2019-08-15. http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-environmental-objectives-system/. Downloaded 2020-05-15.

Umeå Plant Science Center. The Knut and Alice Wallenberg Foundation approved large projects on tree research. Updated 2019-01-14. https://www.upsc.se/about-upsc/news/5457-the-knut-and-alice-wallenberg-foundation-funds-a-large-project-on-spruce-and-pine-research.html Downloaded 2020-05-15.

Umeå University. The status of genetic diversity in Swedish conifer forests: are there reasons for concern? https://www.umu.se/en/research/projects/the-status-of-genetic-diversity-in-swedish-conifer-forests-are-there-reasons-for-concern-/ Downloaded 2020-05-08.

Skogsstyrelsen. Nationell strategi för formellt skydd av skog. https://www.skogsstyrelsen.se/globalassets/aga-skog/skydda-skog/nationell-strategi-for-formellt-skydd-av-skog.pdf. Downloaded 2020-05-15.

Bioversity International. European Information System on Forest Genetic Resources, EUFGIS, http://portal.eufgis.org/ Downloaded 2020-05-15.

Official Journal of the European Communities. Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0105&from=EN. Downloaded 2020-05-15.

European Commission. Plant health and biosecurity. New EU plant health rules, https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation/new_eu_rules_en. Downloaded 2020-05-15.

European Commission. FOREMATIS - Forest Reproductive Material Information System http://ec.europa.eu/forematis/. Downloaded 2020-05-15.

Skogskunskap. Plantvall Tall. https://www.skogskunskap.se/rakna-med-verktyg/foryngring/plantval-tall/. Downloaded 2020-05-15.

Swedish Forest Agency. About us. https://www.skogsstyrelsen.se/en/about-us/. Downloaded 2020-05-15.

European Forest Genetic Resources Programme, Euforgen, http://www.euforgen.org/ Downloaded 2020-05-15.

Skogsstyrelsen. Målbilder för god miljöhänsyn. https://skogsstyrelsen.se/malbilder. Downloaded 2020-05-15.

Svenska PEFC. Skogsstandard. https://pefc.se/skogsstandard/. Downloaded 2020-05-15.

FSC. Statistik och fakta. https://se.fsc.org/se-se/fscs-betydelse/statistik-och-fakta. Downloaded 2020-05-15.

Umeå Plant Science Centre. The UPSC for forest biotechnology. https://www.upsc.se/upsc-centre-for-forest-biotechnology.html. Downloaded 2020-05-08.

Umeå Plant Science Centre. Wu, Harry - Quantitative Genetics and Tree Breeding. https://www.upsc.se/researchers/4657-harry-wu-quantitative-genetics-and-tree-breeding.html Downloaded 2020-05-08.

Uppsala Universitet. Genetics of climatic adaptation in trees. http://www.ieg.uu.se/plant/lagercrantz-group/ongoing-research/#gocait. Downloaded 2020-05-08.

SLU. Research at SLU. https://www.slu.se/en/research/. Downloaded 202-05-08.

Ingvarsson lab. Plant genomics and plant breeding. http://www.pkilab.org/wp/. Downloaded 202-05-08.

SLU. Future Forests. https://www.slu.se/en/Collaborative-Centres-and-Projects/future-forests/. Downloaded 202-05-08.

Umeå Plant Science Centre. Genomic selection in Norway spruce, https://www.upsc.se/organization-gsns.html. Downloaded 202-05-08.

SLU. Trees for the future, T4F. https://www.slu.se/en/Collaborative-Centres-and-Projects/trees-and-crops-for-the-future/t4f/. Downloaded 202-05-08.

Skogssällskapet. Forskning. https://www.skogssallskapet.se/forskning.html. Downloaded 2020-05-08.

Föreningen skogsträdsförädling. http://skogstradsforadling.se/. Downloaded 2020-05-08.

FORMAS. Knowledge for a sustainable transformation. https://formas.se/en/start-page.html. Downloaded 2020-05-08.

SNS Nordic Forest Resarch. https://nordicforestresearch.org/. Downloaded 2020-05-08.

Forskarskolan bioteknik, skogsgenetik förädling. Research school in forest genetics, biotechnology and breeding. http://resschool.slu.se/. Downloaded 2020-05-08.

NordGen. About NordGen Forest, https://www.nordgen.org/en/forest/. Downloaded 2020-05-08.

GENTREE, Optimizing the management and sustainable use of forest genetic resources in Europe, http://www.gentree-h2020.eu/. Downloaded 2020-05-08.

AV SKOGSSTYRELSEN PUBLICERADE RAPPORTER:

2012:1 Kommunikationsstrategi för Renbruksplan
2012:2 Förstudierapport, dialog och samverkan mellan skogsbruk och rennäring
2012:3 Hänsyn till kulturmiljöer – resultat från P3 2008–2011
2012:4 Kalibrering för samsyn över myndighetsgränserna avseende olika former av dikningsåtgärder i skogsmark
2012:5 Skogsbrukets frivilliga avsättningar
2012:6 Långsiktiga effekter på vattenkemi, öringbestånd och bottenfauna efter ask- och kalkbehandling i hela avrinningsområden i brukad skogsmark – utvärdering 13 år efter åtgärder mot försurning
2012:7 Nationella skogliga produktionsmål – Uppföljning av 2005 års sektorsmål
2012:8 Kommunikationsstrategi för Renbruksplan – Är det en fungerande modell för samebyarna vid samråd?
2012:9 Ökade risker för skador på skog och åtgärder för att minska riskerna
2012:10 Hänsynsuppföljning – grunder
2012:11 Virkesproduktion och inväxning i skiktad skog efter höggallring
2012:12 Tillståndet för skogsgenetiska resurser i Sverige. Rapport till FAO

2013:1 Återväxtstöd efter stormen Gudrun
2013:2 Förändringar i återväxtkvalitet, val av föryngringsmetoder och trädslagsanvändning mellan 1999 och 2012
2013:3 Hänsyn till forn- och kulturlämningar – Resultat från Kulturpolytaxen 2012
2013:4 Hänsynsuppföljning – underlag inför detaljerad kravspecifikation, En delleverans från Dialog om miljöhänsyn
2013:5 Målbilder för god miljöhänsyn – En delleverans från Dialog om miljöhänsyn

2014:1 Effekter av kvävegödsling på skogsmark – Kunskapssammanställning utförd av SLU på begäran av Skogsstyrelsen
2014:2 Renbruksplan – från tanke till verklighet
2014:3 Användning och betydelsen av RenGIS i samrådsprocessen med andra markanvändare
2014:4 Hänsynen till forn- och kulturlämningar – Resultat från Hänsynsuppföljning Kulturmiljöer 2013
2014:5 Förstudie – systemtillsyn och systemdialog
2014:6 Renbruksplankonsept – ett redskap för samhällsplanering
2014:7 Förstudie – Artskydd i skogen – Slutrapport

2015:1 Miljöövervakning på Obsytorna 1984–2013 – Beskrivning, resultat, utvärdering och framtid
2015:2 Skogsmarksgödsling med kväve – Kunskapssammanställning inför Skogsstyrelsens översyn av föreskrifter och allmänna råd om kvävegödsling
2015:3 Vegetativt förökat skogsodlingsmaterial
2015:4 Global framtida efterfrågan på och möjligt utbud av virkesråvara
2015:5 Satellitbildskartering av lämnad miljöhänsyn i skogsbruket – en landskapsansats
2015:6 Lägsta ålder för föryngringsavverkning (LÅF) – en analys av följder av att sänka åldrarna i norra Sverige till samma nivå som i södra Sverige
2015:7 Hänsynen till forn- och kulturlämningar – Resultat från Hänsynsuppföljning Kulturmiljöer 2014
2015:8 Uppföljning av skogliga åtgärder längs vattendrag för att gynna lövträd och lövträdsetablering.
2015:9 Ångermanälvsprojektet – förslag till miljöförbättrande åtgärder i mellersta Ångermanälven och nedre Fjällsjöälven
2015:10 Skogliga konsekvensanalyser 2015–SKA 15
2015:11 Analys av miljöförhållanden – SKA 15
2015:12 Effekter av ett förrändrat klimat–SKA 15
2015:13 Uppföljning av skogliga åtgärder längs vattendrag för att gynna lövträd och lövträdsetablering

2016:1 Uppföljning av biologisk mångfald i skog med höga naturvärden – Metodik och genomförande
2016:2 Effekter av klimatförändringar på skogen och behov av anpassning i skogsbruket
2016:3 Kunskapssammanställning skogsbruk på torvmark
2016:4 Alternativa skogsskötselmetoder i Vildmarksriket – ett pilotprojekt
2016:5 Hänsyn till forn- och kulturlämningar – Resultat från Hänsynsuppföljning Kulturmiljöer 2015
2016:6 METOD för uppföljning av miljöhänsyn och hänsyn till rennäringen vid stubbskörd
2016:7 Nulägesbeskrivning om nyckelbiotoper
2016:8 Möjligheter att minska stabilitetsrisker i raviner och slänter vid skogsbruk och exploatering – Genomgång av ansvar vid utförande av skogliga förändringar, ansvar för tillsyn samt ansvar vid inträffad skada
2016:9 Möjligheter att minska stabilitetsrisker i raviner och slänter vid skogsbruk och exploatering – Exempelsamling
2016:10 Möjligheter att minska stabilitetsrisker i raviner och slänter vid skogsbruk och exploatering – Metodik för identifiering av slänter och raviner känsliga för vegetationsförändringar till följd av skogsbruk eller expoatering
2016:11 Möjligheter att minska stabilitetsrisker i raviner och slänter vid skogsbruk och exploatering – Slutrapport
2016:12 Nya och reviderade målbilder för god miljöhänsyn – Skogssektors gemensamma målbilder för god miljöhänsyn vid skogsbruksåtgärder
2016:13 Målanpassad ungskogsskötsel
2016:14 Översyn av Skogsstyrelsens beräkningsmodell för bruttoavverkning

2017:2 Alternativa skötselmetoder i Rånddalen – Ett projekt i Härjedalen
2017:4 Biologisk mångfald i nyckelbiotoper – Resultat från inventeringen – ”Uppföljning biologisk mångfald” 2009–2015
2017:5 Utredning av skogsvårdslagens 6 §
2017:6 Skogsstyrelsens återväxtuppföljning – Resultatet från 1999–2016
2017:7 Skogsträdens genetiska mångfald: status och åtgärdesbehov
2017:8 Skogsstyrelsens arbete för ökad klimatanpassning inom skogsssektorn – Handlingsplan
2017:9 Implementering av målbilder för god miljöhänsyn – Regeringsuppdrag

2017:10 Bioenergi på rätt sätt – Om hållbar bioenergi i Sverige och andra länder – En översikt initierad av Miljömålsrådet
2017:12 Projekt Mera tall! – 2010–2016
2017:13 Skogens ekosystemtjänster – status och påverkan

2018:1 Produktionshöjande åtgärder – Rapport från samverkansprocess skogsproduktion
2018:2 Effektiv skogsskötsel – Delrapport inom Samverkan för ökad skogsproduktion
2018:3 Infrastruktur i skogsbruket med betydelse för skogsproduktionen: Nuläge och åtgärdsförslag – Rapport från arbetsgrupp 2 inom projekt Samverkansprocess skogsproduktion
2018:4 Åtgärder för att minska skador på skog – Rapport från samverkansprocess skogsproduktion
2018:5 Samlad tillsynsplan 2018
2018:6 Uppföljning av askåterföring efter spridning
2018:7 En analys av styrmedel för skogens sociala värden – Regeringsuppdrag
2018:8 Tillvarata jobbpotentialen i de gröna näringarna – Naturnära jobb – Delredovisning av regeringsuppdrag
2018:9 Slutrapport – Gemensam inlämningsfunktion för skogsägare – Regeringsuppdrag
2018:10 Nulägesbeskrivning av nordvästra Sverige
2018:11 Vetenskapligt kunskapsunderlag för nyckelbiotopsinventeringen i nordvästra Sverige
2018:12 Statistik om skogsägande/Strukturstatistik
2018/13 Föreskrifter för anläggning av skog – Regeringsuppdrag
2018:14 Tillvarata jobbpotentialen i de gröna näringarna – Naturnära jobb – Delredovisning av regeringsuppdrag
2018:15 Förslag till åtgärder för att kompensera drabbade i skogsbruket för skador med anledning av skogsbränderna sommaren 2018 – Regeringsuppdrag

2019:1 Indikatorer för miljökvalitetsmålet Levande skogar
2019:2 Fördjupad utvärdering av Levande skogar 2019
2019:3 Den skogliga genbanken – från storhetstid till framtid
2019:4 Åtgärder för en jämnställd skogssektor
2019:5 Slutrapport Tillvarata jobbpotentialen i de gröna näringarna – Naturnära jobb
2019:6 Nya målbilder för god miljöhänsyn vid dikesrensning och skyddsdikning
2019:7 Återkolonisering av hjortdjur inom brandområdet i Västmanland
2019:8 Samverkan Tiveden
2019:9 Samlad tillsynsplan 2019
2019:10 Förslag till åtgärder på kort och lång sikt för att mildra problem i områden med multiskadad ungskog i Västerbottens- och Norrbottens län
2019:11 Föryngringsarbetet efter skogsbranden i Västmanland 2014
2019:12 Utveckling av metod för nyckelbiotopsinventering i nordvästra Sverige
2019:13 Regler och rekommendationer för skogsbränsleuttag och kompensationsåtgärder – Kunskapsunderlag
2019:14 Regler och rekommendationer för skogsbränsleuttag och kompensationsåtgärder – Vägledning
2019:15 Underlag för genomförande av direktivet om främjande av användningen av energi från förnybara energikällor
2019:16 Skogsbrukets kostnader för viltskador
2019:17 Omvärldsanalys svensk skogsnäring
2019:18 Statistik om formellt skyddad skogsmark, frivilliga avsättningar, hänsynsytor samt improduktiv skogsmark – Redovisning av regeringsuppdrag
2019:19 Attityder till nyckelbiotoper – Nulägesbeskrivning 2018
2019:20 Kulturmiljöer – en självklar del i skogslandskapet
2019:21 Skogssektorns gemensamma målbilder för god miljöhänsyn – nya och reviderade målbilder. Målbilder för kulturmiljöer/övriga kulturhistoriska lämningar
2019:22 Samlad tillsynsplan 2019
2019:23 Klimatanpassning av skogen och skogsbruket – mål och förslag på åtgärder
2019:24 Skogsskötsel med nya möjligheter – Rapport från Samverkansprocess skogsproduktion
2019:25 Mera Tall 2016-2019 – Redovisning/utvärdering (av annat projekt än regeringsuppdrag)

2020:1 Inverkan av skogsbruksåtgärder på kvicksilvers transport, omvandling och upptag i vattenlevande organismer
2020:2 Registrering av nyckelbiotoper i samband med avverkningsanmälningar och tillståndsansökningar Syntes och rekommendationer
2020:3 The second report on The state of the world´s forest genetic resources
2020:4 Forest management in Sweden Current practice and historical background
2020:5 Kontrollinventering av hänsynsuppföljningen före avverkning – Analys
2020:6 Utveckling och samverkan om nyckelbiotoper 2017-2019

AV SKOGSSTYRELSEN PUBLICERADE MEDDELANDEN

Under 2017 slogs Skogsstyrelsens publikationer Rapport och Meddelande ihop till en med namnet Rapport.

2012:1 Förslag på regelförenklingar i skogsvårdslagstiftningen
2012:2 Uppdrag om nationella bestämmelser som kompletterar EU:s timmerförordning
2012:3 Beredskap vid skador på skog
2013:1 Dialog och samverkan mellan skogsbruk och rennäring
2013:2 Uppdrag om förslag till ny lagstiftning om virkesmätning
2013:3 Adaptiv skogsskötsel
2013:4 Ask och askskottsjukan i Sverige
2013:5 Förstudie om ett nationellt skogsprogram för Sverige – Förslag och ställningstaganden
2013:6 Förstudie om ett nationellt skogsprogram för Sverige – omvärldsanalys
2013:7 Ökad jämställdhet bland skogsägare
2013:8 Naturvårdsavtal för områden med sociala värden
2013:9 Skogens sociala värden – en kunskapssammanställning
2014:1 Översyn av föreskrifter och allmänna råd till 30 § SvL – Del 2
2014:2 Skogslandskapets vatten – en lägesbeskrivning av arbetet med styrmedel och åtgärder
2015:1 Förenkling i skogsvårdslagstiftningen – Redovisning av regeringsuppdrag
2015:2 Redovisning av arbete med skogens sociala värde
2015:3 Rundvirkes- och skogsbränslebalanser för år 2013 – SKA 15
2015:4 Renskogsavtal och lägesbeskrivning i frågor om skogsbruk – rennäring
2015:6 Utvärdering av ekonomiska stöd
2016:1 Kunskapsplattform för skogsproduktion – Tillståndet i skogen, problem och tänkbara insatser och åtgärder
2016:2 Analys av hur Skogsstyrelsen verkar för att miljömålen ska nås
2016:3 Delrapport – Främja anställning av nyanlända i de gröna näringarna och naturvården
2016:4 Skogliga skattningar från laserdata
2016:5 Kulturarv i skogen
2016:6 Sektorsdialog 2014 och 2015
2016:7 Adaptiv skogsskötsel 2013–2015
2016:8 Agenda 2030 – underlag för genomförande – Ett regeringsuppdrag
2016:9 Implementering av målbilder för god miljöhänsyn
2016:10 Gemensam inlämningsfunktion för skogsägare
2016:11 Samlad tillsynsplan 2017
2017:1 Skogens sociala värden i Skogsstyrelsens rådgivning och information
2017:2 Främja nyanländas väg till anställning i de gröna näringarna och naturvården
2017:3 Regeringsuppdrag om jämställdhet i skogsbruket
2017:4 Avrapportering av regeringsuppdrag om frivilliga avsättningar

PUBLICERING OCH BESTÄLLNING AV SKOGSSTYRELSENS RAPPORTER

Skogsstyrelsens rapporter publiceras som pdf-filer på vår webbplats: www.skogsstyrelsen.se/om-oss/publikationer/

Äldre publikationer kan beställas eller laddas ned i webbutiken: shop.skogsstyrelsen.se/sv/publikationer/

Skogsstyrelsen publicerar dessutom foldrar, broschyrer, böcker med mera inom skilda skogliga ämnesområden. Skogsstyrelsen är också utgivare av tidningen Skogseko.

Beställning av publikationer och trycksaker:
Skogsstyrelsen,
Böcker och broschyrer
551 83 JÖNKÖPING

Telefon: 036-35 93 40, 036-35 93 00 (vx)
e-post: bocker@skogsstyrelsen.se
webbutik: shop.skogsstyrelsen.se/sv/

Skogen och skogsgenetiska resurser är värdefulla för Sveriges ekonomi, miljö och samhälle. Denna rapport beskriver tillstånd och åtgärdsbehov för skogsgenetiska resurser i Sverige. Förhoppningen är att rapporten resulterar i relevanta åtgärder för bland annat en hållbar användning, vidare forskning och policyutveckling av skogsgenetiska resurser. Rapporten har tagits fram på uppdrag av regeringen och FN:s livsmedels- och jordbruksorganisation, FAO.

Sweden's landscape is dominated by forest and forest genetic resources are of vital importance for economical, ecological and social values. This report presents the statuses and action needs for forest genetic resources in Sweden. The Swedish Forest Agency hopes that the report will lead to adequate measures, primarily concerning the sustainable use of forest genetic resources and necessary research and policy development.

SKOGSSTYRELSEN

skogsstyrelsen.se