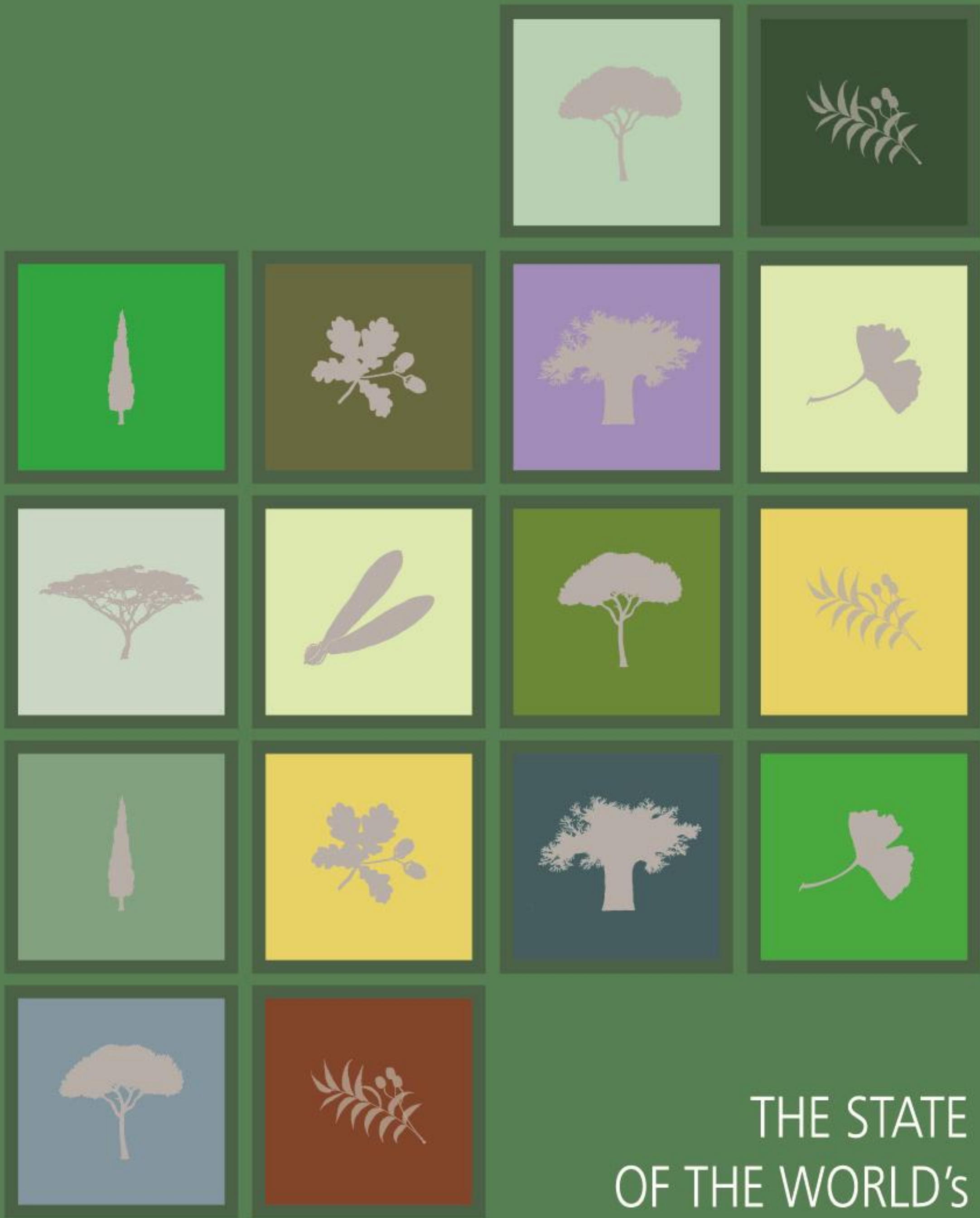

THE STATE
OF THE WORLD's
FOREST GENETIC RESOURCES

COUNTRY REPORT

SWEDEN

This country report is prepared as a contribution to the FAO publication, The Report on the State of the World's Forest Genetic Resources. The content and the structure are in accordance with the recommendations and guidelines given by FAO in the document Guidelines for Preparation of Country Reports for the State of the World's Forest Genetic Resources (2010). These guidelines set out recommendations for the objective, scope and structure of the country reports. Countries were requested to consider the current state of knowledge of forest genetic diversity, including:

- Between and within species diversity
- List of priority species; their roles and values and importance
- List of threatened/endangered species
- Threats, opportunities and challenges for the conservation, use and development of forest genetic resources

These reports were submitted to FAO as official government documents. The report is presented on www. fao.org/documents as supportive and contextual information to be used in conjunction with other documentation on world forest genetic resources.

The 1st Report on the State of the World´s Forest Genetic Resources

Country Report: Sweden

Sanna Black-Samuelsson

SKOGSSTYRELSEN
SWEDISH FOREST AGENCY

CONTENTS

Executive summary

Sweden is a forest dominated country. 70 % of the land area, 286 000 square km, is forested mainly with the native species *Pinus sylvestris*, *Picea abies* and *Betula pendula*. Forestry is crucial for the national economy and provides by far the largest net export income, USD 17.5 billion. 96 000 people are employed in the forestry sector in Sweden. The total export value of forest products worldwide was worth USD 189 billion. Sweden accounted for seven percent of that amount.

In addition to production, the environmental forest values are highly appreciated. Two overriding goals, production and environmental protection, are according to the national legislation, on equal footing in Swedish forestry. In 1994, the policy structure for forestry changed, and informative means of control was emphasized in a system with “freedom under responsibility”.

About half of all forest land in Sweden is owned by family enterprises. In year 2010 there were about 330 000 forest owners, of whom 38 % were females and 62 % were males. In 2010, the number of forest entities, owned by single owners, was 228 000.

Genetic variation is a prerequisite for the long-term survival and reproduction of forest trees in a changing environment. As a consequence of climate change, an increased forest production, a more widespread use of exotic tree species and an increased international marketing with forest reproductive material, there is a significantly increased need for gene conservation of native forest trees. In addition, genetic variation increases the possibilities of forest trees to cope with forest damage.

Genetic resources of *Pinus sylvestris*, *Picea abies* and *Betula pendula* are managed within breeding programs. The objectives of these programs include improvement of economic tree performance, preparation for climatic change and management of the gene resource (conservation to a limited extent). For the above mentioned species, as well as for all other forest trees native to Sweden, no satisfactory *in situ* or *ex situ* conservation of genetic resources currently exists.

This report presents a proposal aiming to improve the gene conservation of a majority of the native forest trees in Sweden. Given that 840 000 hectares of productive forest land is formally protected, voluntary conservation areas comprise another 1.2 million hectares and that the total share of forest land exempted from forestry is approximately 25 %, the idea is to utilize certain kinds of protected areas for *in situ* forest gene conservation. This topmost prioritized approach allows for cost-efficient sustainable and dynamic gene conservation of several tree species in each protected area, as well as conservation of associated species in their natural environment. In addition, the simultaneous conservation of ecological, aesthetical, ethical and cultural heritage values is enabled.

In order to achieve a practical and sustainable *in situ* forest gene conservation in Sweden, the need of additional economic resources needs some consideration. Also, national legislation on certain protected areas requires amendments. In addition, officers responsible for the handling and management of protected areas need elementary information on theoretical and practical aspects of gene conservation of forest trees. Concerning *ex situ* forest gene conservation, resources are required to carry out seed collections of prioritized tree species, for instance for preservation in the Svalbard seed vault.

Access to multiple tree species is a means to meet unexpected effects of climate change as well as future demand of suitable forest reproductive material. Using several tree species´ will increase the degrees of freedom for the forest owner and decrease the vulnerability when it comes to forest regeneration. For that reason, additional tree species, mostly broad-leaves, need to be incorporated in breeding and genetic conservation programs in Sweden. This calls for an investigation of the existing broad-leaved genetic resources in order to develop forest reproductive material that is adapted to the right climatic conditions (adaption assisted migration).

The international information exchange in forest gene conservation and forest tree breeding presently is extensive and useful. Also research cooperation and education on forest tree breeding and related subjects is of high quality. On the other hand, the knowledge of and education on the significance of forest genetic resources for purposes other than breeding is insufficient. It is recommended that the extent of this subject is increased in relevant forestry courses and educations.

The ownership, access and benefit sharing of forest genetic resources today constitute an open and smooth system in the Nordic countries. This situation may be changed with an increased trade with forest reproductive material from southern countries with different regulatory framework. Also, the possible ratification of the Nagoya Protocol and possible patenting of genetic material may in the future influence the present well functioning access and benefit sharing of forest genetic resources.

It can be concluded that the most urgent points for the future Swedish work on forest genetic resources concern the *in situ* conservation in protected areas as described above. The strategy suggested in this report is in line with the environmental quality objectives *Sustainable Forests* and *A Rich Diversity of Plant and Animal Life*, as adopted by the Swedish Parliament. The strategy is also in accordance with the recent proposal from the All Party Committee on Environmental Objectives to the Swedish government, aiming to increase the knowledge of and attention to the conservation of genetic diversity of species in natural populations and in forestry.

Sammanfattning (in Swedish)

Sverige är ett skogsrike. 70 % av landets yta, 286 000 km^2 är beskogat huvudsakligen av de inhemska skogsträden tall, gran och björk. Skogsbruket är centralt för Sveriges ekonomi och utgör den största exportinkomsten, 128 miljarder kronor. 96 000 personer är anställda inom skogssektorn i Sverige. Det totala exportvärdet av skogsprodukter uppgick till 189 miljarder USD. Sverige svarade för 7 % av detta.

Utöver skogsproduktion är skogen som miljö högt värderad i Sverige. Den svenska skogspolitiken vilar på två jämställda mål, produktionsmålet och miljömålet. 1994 förenklades regelverket för skogsbruket och informativa styrmedel betonades i ett system med ”frihet under ansvar”.

Ungefär hälften av all svensk skogsmark ägs av enskilda skogsägare. År 2010 fanns ca 330 000 skogsägare, varav 38 % var kvinnor och 62 % var män. Antalet brukningsenheter ägda av fysiska personer var ungefär 228 000.

Genetisk variation är en grundläggande förutsättning för att skogsträd långsiktigt ska överleva och reproducera sig i en föränderlig miljö. Som en följd av förändringar i klimat, en ökad skogsproduktion, en mer utbredd användning av främmande trädslag och en tilltagande internationell handel med skogsodlingsmaterial, ökar behovet avsevärt att bevara genetiska resurser av inhemska skogsträd. Därtill behövs genetisk variation för att öka skogsträdens möjligheter att klara angrepp av skadegörare.

Skötsel och hantering av genetiska resurser av inhemska skogsträd sker idag i förädlingsprogram för tall, gran och björk. Förädlingsprogrammen syftar framför allt till att möjliggöra högre tillväxt och kvalitet, liksom beredskap för sjukdomar och klimatförändringar. I en begränsad utsträckning bevaras genetiska resurser. För tall, gran och björk liksom för övriga inhemska skogsträd sker idag inget ändamålsenligt *in situ* eller *ex situ* bevarande av genetiska resurser.

Denna rapport presenterar ett förslag till strategi som syftar till att förbättra genbevarandet av majoriteten av de inhemska skogsträden i Sverige. Med bakgrund av att ungefär 840 000 hektar produktiv skogsmark är formellt skyddad, att frivilligt avsatta områden omfattar ytterligare 1,2 miljoner hektar och totala andelen skogsmark undantagen från skogsbruk är ca 25 %, är idén att använda vissa typer av områdesskydd, framför allt biotopskydd och ekoparker, för *in situ* bevarande av skogsgenetiska resurser. Strategin bidrar till ett kostnadseffektivt uthålligt och dynamiskt genbevarande av flera trädslag i varje skyddat område. Samtidigt bevaras associerade arter i sin livsmiljö och ekologiska, estetiska, etiska och kulturhistoriska värden tas till vara.

För att uppnå ett adekvat och långsiktigt *in situ* bevarande av skogsgenetiska resurser i Sverige, bör behov av ytterligare ekonomiska resurser övervägas. Behov finns också att se över den nationella lagstiftningen för vissa typer av områdesskydd. För att åstadkomma *in situ* bevarande behöver de tjänstemän som ansvarar för handläggning och skötsel av skyddade områden få grundläggande information om teoretiska och pratiska aspekter av genbevarande av skogsträd. För *ex situ* bevarande fodras resurser för att samla in frön av vissa prioriterade skogsträd, bland annat för bevarande i Svalbards genbank.

Tillgänglighet till en mångfald av trädslag är ett verktyg att möta oförutsägbar inverkan av klimatförändringar och framtida efterfrågan på skogsodlingsmaterial. Användning av flera trädslag ökar skogsägarens frihetsgrader och minskar sårbarheten vid föryngringar. Därför bör ytterligare trädslag, framför allt lövträd, inkorporeras i program för förädling och bevarande av genetiska resurser. Som en bas för framtida förädling finns därför behov att undersöka befintliga genresurser av lövträd i syfte att utveckla ett skogsodlingsmaterial som är anpassat till rätt klimatiska förhållanden.

Idag sker ett omfattande och välfungerande internationellt utbyte av information inom skogligt genbevarande och förädling. Även forskningssamarbete och utbildning inom skogsträdsförädling och relaterade ämnesområden är av hög kvalitet. Däremot är kunskapen och undervisningen om betydelsen av skogsgenetiska resurser för andra ändamål än förädling bristfällig. Att öka omfattningen av detta ämne på ett ändamålsenligt sätt under relevanta skogliga kurser och utbildningar är därför att rekommendera.

Ägande, tillträde och vinstdelning av skogsgenetiska resurser representerar idag ett öppet och välfungerande system i de Nordiska länderna. Denna situation kan förändras vid ökad handel med skogsodlingsmaterial från sydligare länder med en annan typ av regelverk. Även den tänkbara ratificeringen av Nagoyaprotokollet och en eventuell patentering av genetiskt material kan i framtiden påverka det idag friktionsfria utbytet av skogsgenetiska resurser.

Sammanfattningsvis är *in situ* bevarande i skyddade områden av skogsgenetiska resurser för samtliga inhemska trädslag det uppenbart mest angelägna arbetet för att åstadkomma ett framtida adekvat genbevarande i Sverige. Stategin som presenterats i denna rapport är i linje med riksdagen miljömål *Levande Skogar* och *Ett Rikt Växt- och Djurliv*, liksom Miljömålberedningens förslag till regeringen att öka kunskapen om och uppmärksamheten på att bevara genetisk variation hos arter i naturliga populationer och i skogsbruket.

Chapter 1.
Introduction to Sweden and its Forest Sector

1.1. Basic information about Sweden

Sweden is located between 55-69° N latitude and 10-24° E longitude and has an area of 450 000 square km. In the west Sweden is bordered by Norway, and in the north Finland. The maximum length is 1 574 km and the maximum width 499 km. In many parts of the country the climate is maritime, but in the inner north and central parts the climate is more continental, with regular snow cover and cold winters. The average annual precipitation ranges between 500 -1 000 mm. Due to the influence of the Gulf Stream the climate allows cultivation above the polar circle. In the west, on the border with Norway, the central Scandinavian mountain range rises. It is an ancient mountain chain, mostly below 2 000 m above sea level, though some peaks are higher (highest Mt. Kebnekaise in the north, 2 900 m).

The population is 9.5 million which gives an average density of 17.7 persons per square km. The most densely populated are the province of Scania in the south, the area around the capital Stockholm, and on the west coast. The population is dominated by Scandinavians and an ethnic group, the Lapps, who manage reindeer in the north. In recent years there has been considerable immigration into the country.

1.2. Forests and forestry in Sweden

1.2.1. Provision of statistics on forests and forestry

The information concerning forests and forestry in Sweden (section 1.2.) is provided by the Swedish National Forest Inventory[1],[2] (the Swedish NFI); and the Swedish Forest Agency[3,4]. The Swedish NFI describes the state and changes in Sweden's forests, and the information collected is used for example as a basis for forestry, energy and environmental policy in Sweden. Data from the Swedish NFI is part of the national official statistics. The responsible authority for official statistics concerning the state and changes in Swedish forests is the Swedish University of Agricultural Sciences (SLU).

The Swedish Forest Agency is the national authority in charge of forest-related issues. Its main function is to promote the kind of management of Sweden's forests that enables the two overriding forest policy objectives, production and environmental protection, to be attained. The Swedish Forest Agency is also responsible for statistics on forests, forestry production and employment in forestry, as well as on environment and social values in forestry.

1 http://pub.epsilon.slu.se/8333/1/Skogsdata2011_webb.pdf

2 Skogsdata 2011. Forestry statistics 2011. Official Statistics of Sweden. Swedish University of Agricultural Sciences. Umeå 2011. ISSN 0280-0543.

3 Swedish Statistical Yearbook of Forestry 2010. Official Statistics of Sweden. Swedish Forest Agency. ISSN 0491-7847. ISBN 978-91-88462-93-0.

4 http://www.skogsstyrelsen.se/Global/myndigheten/Statistik/Skogsstatistisk%20årsbok/01.%20Hela%20-%20Entire/Skogsstatistisk%20årsbok%202010%20(hela).pdf

1.2.2. Forest area and forest types in Sweden

Sweden has 22.5 million hectares of productive forest land (Map 1, annex 1) and about 0.8 million hectares of productive forest land within protected areas. Forest land according to international definitions covers 28.2 million hectares.

The total land area is 40.8 million hectares which is divided into following area (in million hectares): 22.5 productive forest land; 4.4 bog- and marshland; 0.9 rock surfaces; 3.5 mountains and alpine coniferous forest; 3.4 cropland and grazing land and 4.2 protected areas within national parks and nature reserves. The division of land area for productive forest land and other land types between regions in Sweden is shown in Table 1.

Table 1. Land area by land use class in four regions in Sweden and in the whole country between 2006 and 2010. Source: The Swedish National Forest Inventory

Region	**Land-use class**										
	Prod.forest land[1]	**Pasture land**	**Arable land**	**Swamp**	**Rock surface**	**Sub-alpine wood**	**High Mountains**	**Urban land**	**Other land**	**Nature reserves**	**Total**
	1000 hectare										
N Norrland	6709	1	141	2341	148	163	2432	104	174	2974	15187
S Norrland	5649	20	171	1114	164	250	665	149	151	592	8925
Svealand	5180	101	846	670	208	18	17	412	181	415	8049
Götaland	4938	357	1758	308	357			526	193	180	8618
Sweden	**22477**	**480**	**2916**	**4433**	**877**	**431**	**3114**	**1191**	**698**	**4160**	**40778**

1. Includes productive forest land within National parks and Nature reserves not protected from forestry
2. National parks and Nature reserves excluding productive forest land that is not protected from forestry

1.2.3. Standing volume

The standing volume in Sweden's forests has increased consistently since the 1920s when the Swedish NFI first started collecting data. In the middle of the 1920s, the total standing volume was 1 760 million cubic meters (m^3sk), and has increased since then to the current level of 3 400 million m^3sk. This represents an increase of 86 %. This steady increase indicates a long term trend of higher growth than loss (natural loss and fellings) during the period. The reason for this increase is the production and growth based forest management introduced with the more intensive forest use which started at the beginning of the 20th century. The increase in standing volume since the 1950s is shown in Figure 1.

Total standing volume on productive forest land is today about 2.9 billion cubic meters, of which 39 % is *Pinus sylvestris*, 42 % is *Picea abies* and 12 % is *Betula pendula*. Average standing volume per hectare is 130 cubic meters. The total standing volume of Swedish forests has increased by over 80 % since the 1920s. The average annual productivity of forest land is 5.3 cubic meters per hectare. Total annual growth is approximately 111 million cubic meters for productive forest and approximately 117 million cubic meters for all land use classes.

The domination by *Pinus sylvestris* and *Picea abies* in Sweden's forests is natural considering that the majority of the country lies within the boreal region. The increase seen in standing volume was primarily in *Picea abies* up until the 1970s, since then the increase in standing volume is from *Picea abies*, *Pinus sylvestris* and broadleaves. In recent years, the volume of *Picea abies* has stabilized and volume increases are primarily due to *Pinus sylvestris* and broadleaves.

The proportion of broadleaves has increased from 15 % at the end of 1950 to 19 % today. Sweden is now back to the same proportion of broadleaves as was seen in the 1920s. Since the 1990s, the proportion of *Picea abies* has decreased from 45 % to 40 %, mainly as an effect of the severe storms in southern Sweden during the past few years which primarily affected medium aged *Picea abies* forests. The volume of dead and wind thrown trees has been relatively constant, with a slight increase due to storms at the end of the 1960s. An increase can be seen however for the last 10-15 years and the proportion dead and wind thrown trees is now 3 % of the total standing volume.

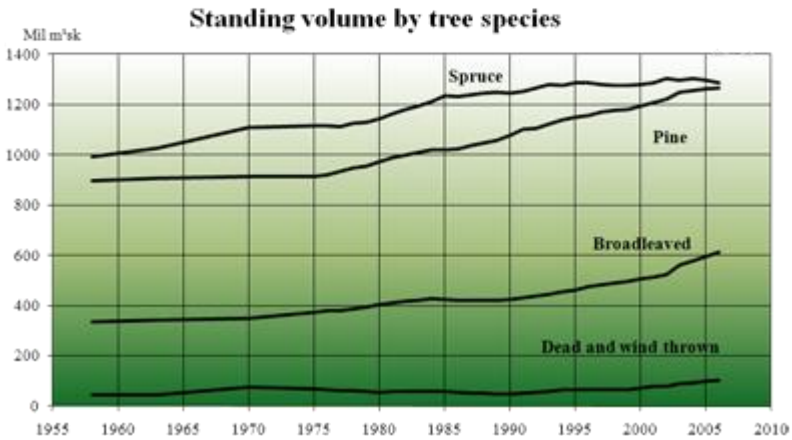

Figure 1. Increase in standing volume for Picea abies (spruce), Pinus sylvestris (pine) and broadleaved species in Sweden since the 1950s. Source: The Swedish National Forest Inventory.

1.2.4. Estate and ownership structure

The distribution of productive forest land by ownership in Sweden is 50 % individual owners, 26 % private owned companies, 14 % state owned companies, 6 % other private owners, 3 % state and 1 % other public owners.

In 2010, there were about 330 000 forest owners, of whom 38 % were females and 62 % were males. The number of forest entities, owned by single owners, was 228 000, of which 68 % were locally owned, 24 % were owned by non-residents and 8 % partly by non-residents. In the end of 2010, the Swedish forest owners' associations had more than 110 000 members with a total area of almost 6.2 million hectares.

The geographic distribution of forest types and the forest plantations percentage of the productive forest area in Sweden are shown in Table 2. Table 2 also presents the organization / subdivision of the forest sector into the ownership classes companies, other private owners and public bodies. It is evident that private owners own approximately half the forest land area and the remaining areal are equally divided between companies and public bodies.

Table 2. Geographic distribution of forest types and the productive forest area for different forest types by ownership categories in Sweden. Pine = Pinus sylvestris; Spruce = Picea abies, Cont = Pinus contorta; Broadl = broadleaved tree species. Source: The Swedish National Forest Inventory

Region	Ownership	Productive land area	Forest Type							
			Pine	Spruce	Cont	Mixed Conifer	Conifer/ Broadl.	Other Broadl.	Valuable Broadl.	Bare
		1000 ha	% av productive forest area							
N Norrland	Companies	1 036	48.5	15.1	7.3	15.2	7.1	3.5	0.0	3.4
	Other private owners	2 539	46.8	17.0	1.0	15.5	9.8	6.7	0.0	3.1
	Public bodies	3 100	55.5	15.2	2.8	13.1	7.7	3.6	0.0	2.1
	All	6 674	51.1	15.9	2.8	14.4	8.4	4.7	0.0	2.7
S Norrland	Companies	2 530	36.8	26.9	8.0	14.5	8.1	3.3	0.0	2.5
	Other private owners	2 558	29.6	33.3	1.3	15.9	10.0	5.8	0.0	4.0
	Public bodies	682	40.8	27.2	2.8	16.3	5.9	4.0	0.0	3.1
	All	5 771	34.1	29.8	4.4	15.3	8.7	4.5	0.0	3.2
Svealand	Companies	1 425	42.6	28.5	1.6	14.5	5.6	3.3	0.1	3.9
	Other private owners	2 672	34.7	27.2	0.2	17.8	7.7	8.3	0.4	3.7
	Public bodies	1 058	52.5	19.5	0.4	15.3	4.3	4.8	0.4	2.8
	All	5 155	40.5	26.0	0.6	16.4	6.4	6.2	0.3	3.6
Götaland	Companies	284	30.4	38.0	0.0	9.5	6.0	6.9	3.6	5.6
	Other private owners	3 955	22.8	38.9	0.0	13.0	7.0	9.4	4.2	4.7
	Public bodies	704	32.4	34.1	0.0	11.9	6.3	8.1	3.8	3.4
	All	4 944	24.6	38.2	0.0	12.7	6.8	9.1	4.1	4.6
Whole country	Companies	5 275	40.3	25.6	5.7	14.4	7.1	3.5	0.2	3.2
	Other private owners	11 724	32.2	30.3	0.6	15.3	8.4	7.8	1.5	4.0
	Public bodies	5 544	50.2	19.9	2.0	13.8	6.7	4.4	0.6	2.5
	All	**22 543**	**38.5**	**26.6**	**2.1**	**14.7**	**7.7**	**6.0**	**1.0**	**3.5**

1.2.5. Productivity and forest growth

The forest productivity (cubic meter standing volume per hectare and year, m^3sk/ha/yr) is an expression of a sites growth potential. Productivity is highest in the very south of Sweden (11.2 m^3sk/ha/yr) and decreases as you move north and then northwest (Map 2, Annex II). The average site productivity for the whole country is 5.3 m^3sk/ha/yr. The productivity values for each region (m^3sk/ha/yr) are 3.0 for Northern Norrland, 4.2 for Southern Norrland, 6.2 for Svealand and 8.6 for Götaland. The regions in Sweden are shown in Figure 2.

There has been a trend of increasing growth since the 1970s which seems to have stabilized at 120 million m^3sk (Map 3, Annex III). Since the 1920s, growth increased by more than 50% from approximately 60 to 120 million m^3sk per year. Mean growth for productive forest land in Sweden is 4.9 m^3sk/ha/yr. Respective values for the different regions in m^3sk/ha/yr are 2.9 for Northern Norrland; 4.5 for Southern Norrland, 5.6 for Svealand and 7.3 for Götaland.

Figure 2. The division of Sweden into the regions Götaland, Svealand, Southern and Northern Norrland.

1.2.6. Fellings

The annual growth, loss and fellings in Swedish forests since the 1950s are shown in Figure 3. For a short period at the start of the 1970s, total loss (natural loss and fellings) was close to total growth. Since then total loss has decreased and the difference between total loss and growth increased to close to 40 million m^3sk. During the 1980s and 1990s this difference has slowly reduced to today level of approximately 15 million m^3sk.

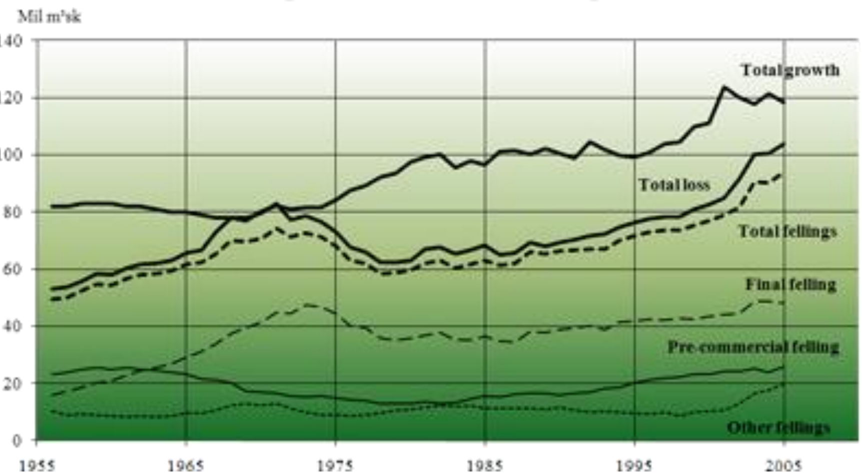

Figure 3. Annual growth, loss and fellings in Swedish forests since the 1950´s. Source: The Swedish National Forest Inventory.

Since the 1950's, there has been less pre-commercial felling and more final felling in Swedish forests. Final felling was at a maximum at the start of the 1970s and subsequently decreased. In recent years final felling has steadily increased again. Pre-commercial felling was at its lowest during the 1980s and has since then increased steadily. Within the class "other fellings" is felling of seed trees, standard trees, single trees and wind thrown trees. The sharp increase in this category seen under recent years is due to the effects of the storms “Gudrun” in 2005 and “Per” in 2007. The natural loss (total loss minus total felling) provides an indicator for the potential future volume of dead wood.

According to the gross felling model by the Swedish Forest Agency, the total volume of felled timber during 2009 was about 89.5 million cubic meters standing volume. The net felling volume was 72.8 million cubic meters solid timber excluding bark divided accordingly (in million cubic meters): 35.8 of sawlogs; 30.6 of pulpwood; 5.9 of fuelwood and 0.5 of other sorts.

According to the Swedish NFI, 942 000 hectares were logged during 2010. Of those, final fellings were carried out on 200 000 hectares; 433 000 hectares were thinned and 309 000 hectares were cleared. Annual harvest by tree species between 1998/99 and 2008/09 is shown in Table 3.

The mean area of reported regeneration fellings was 4.2 hectares. During 2010, the Swedish Timber Measurement Council graded 95.5 million cubic meters of solid timber. Of that amount, 37.2 million cubic meters was sawlogs, 41.5 million cubic meters was pulpwood (including tree parts), 10.2 million cubic meters was chips, and 6.5 million cubic meters consisted of sawdust, bark and biofuel.

Table 3. Annual harvest by tree species between 1998/99 and 2008/09 for all land use classes excluding alpine and urban areas. m³sk is the cubic meter standing volume per hectare and year. Source: The Swedish National Forest Inventory

	Tree species (million m³sk)			
Felling season	Pinus sylvestris	Picea abies	Broadleves	All
1998/99	18.9	31.1	5.3	55.2
1999/00	17.8	41.4	5.5	64.7
2000/01	23.9	35.1	6.9	65.8
2001/02	27.6	40.4	4.6	72.6
2002/03	29.8	40.7	5.9	76.3
2003/04	30.4	41.5	7.9	79.8
2004/05	33.1	50.9	8.1	92.1
2005/06	25.5	42.9	8.3	76.7
2006/07	27.5	54.1	6.5	88.1
2007/08	24.4	33.6	6.2	64.2
2008/09	21.4	33.3	8.7	63.4

1.2.7. Economy

The gross value of timber felled during 2009 was USD 3.2 billion. Felling costs amounted to about USD 1.1 billion, and the net conversion value (gross value minus felling costs) was USD 2.1 billion. Costs for silvicultural measures, pre-commercial thinning, fertilizer, maintenance and new investments in roads and ditches totaled USD 0.5 billion.

Logging costs during 2009 were USD 10.6 per cubic meters solid volume including bark (m³fpb) for regeneration fellings and USD 21.5 per m³fpb for thinning and clearing. The gross output of the forest sector during 2008 was USD 29 billion. During 2008, the value added by the forest products industry amounted to 9.8 % of the total value added by the manufacturing industry. During the same year, the total value added by forestry and the forest products industry equaled 2.2 % of the gross domestic product.

The export value of forestry and the forest products industry during 2010 was USD 17.5 billion. The forestry and forest industry sectors accounted for 11 % of the total export value (all goods). The assessed tax value of productive forest land for 2010 totaled about USD 58 billion.

During 2010, compensation totaling USD 18.8 million were awarded to forest owners for habitat protection, along with about USD 2.7 million for nature conservation agreements.

In 2010, the following volumes (cubic meters solid volume excluding bark, m^3f ub) of raw materials were stockpiled in Sweden: 3.4 million of coniferous sawlogs, 3.4 million of pulpwood and 0.5 million of chips. The consumption during 2009 of roundwood by the forest products industry was 67.4 million m^3f ub, of which 38 % was *Pinus sylvestris*, 52 % *Picea abies*, 8 % *Betula pendula* and 1 % other broad-leaved species. During 2009, the forest products industry's consumption of wood fiber was 78.5 million m^3f ub. Of that amount the consumption in million m^3f ub was 43.8 for the pulp and paper industry, 33.4 for sawmills (which generated 11.1 of by-products for use in the pulp and wood-panel industries), and 1.1 for the wood-panel industry.

1.2.8. Education and labor force

In 2010, approximately 95 700 people, of which 15 500 were females and 80 200 were males, were employed in the forest sector: 29 900 were forestry employees, 35 200 worked for wood processing industries and 30 600 worked for the pulp, paper and paperboard industry.

During the same year, Sweden's business register covered 105 000 workplaces in forestry, 5 500 workplaces in wood processing industries and 350 workplaces in pulp, paper and paperboard industries. The between year variation in numbers of workplaces in forestry is probably explained by the uncertainty in the coding of the branch of industry.

In 2010, large-scale forestry employed about 2 200 people. Forest contracting companies employed 14 700 people. The number of hours worked in forestry amounted to 28.4 million, out of which 11.8 million hours were in the individual owners' sector.

The number of graduates with forestry education from the Swedish University of Agricultural Science during the academic year 2009/10 were 19 Bachelor of Science in Forest Engineering and 57 Advanced Master of Science in Forestry.

1.3. Environmental quality objectives[5]

The Swedish Parliament has adopted environmental quality objectives and interim targets for sustainable development. The objectives define the quality and state of Sweden's environment and of its natural and cultural resources that are sustainable in the long term.

The Swedish Government bears overall responsibility for the environmental quality objectives. The Swedish Environmental Protection Agency (Swedish EPA) coordinates follow-up, provision of information and the use of economic impact assessments within the environmental objectives system. An All Party Committee on Environmental Objectives has been set up to secure broad political consensus on environmental issues. Seven national agencies, among them the Swedish Forest Agency, have been assigned one or more of the environmental quality objectives, which it is their job to follow up and evaluate. Other agencies work within their respective sectors to promote progress towards the objectives.

5 http://www.miljomal.nu/Environmental-Objectives-Portal/Undre-meny/About-the-Environmental-Objectives/

In their capacity as regional environmental agencies, the county administrative boards play an important and coordinating role in work to achieve the environmental objectives. The Swedish municipalities have an essential role in the work of achieving the environmental objectives. By translating national and regional objectives into local aims and actions, they can make the objectives effective tools in local politics.

A number of agencies bear responsibility for working to attain the relevant environmental quality objectives in their respective sectors. The business sector, in cooperation with other stakeholders, has a substantial role in achieving the environmental quality objectives. Today, many companies are engaged in structured environmental work that has a major bearing on the environment. The environmental organizations are continuously engaged in a range of issues that are directly linked to the various environmental objectives.

Several of the sixteen environmental quality objectives have connection with forestry. Two of them, *Sustainable Forests* (1.3.1.) and *A Rich Diversity of Plant and Animal Life* (1.3.2.), have a very clear and close connection with forest genetic diversity.

1.3.1. Sustainable Forests[6]

The environmental quality objective Sustainable Forests states that "the value of forests and forest land for biological production must be protected, at the same time as biological diversity, cultural heritage and recreational assets are safeguarded". The Swedish Forest Agency is the responsible authority for Sustainable Forests. The following outcomes are connected with the conservation of forest genetic resources and are intended to be achieved within a generation: i) The natural functions and processes of forest ecosystems will be maintained; and ii) There will be viable populations of native plant and animal species living in natural conditions. The Environmental Objectives Council's assessment is that the objective Sustainable Forests will be very difficult or not possible to achieve by 2020, even if further action is taken. No clear trend in the state of the environment can be seen.

1.3.2. A Rich Diversity of Plant and Animal Life[7]

The environmental quality objective *A Rich Diversity of Plant and Animal Life* states that biological diversity must be preserved and used sustainably for the benefit of present and future generations. Species habitats and ecosystems and their functions and processes must be safeguarded. Species must be able to survive in long-term viable populations with sufficient genetic variation. Finally, people must have access to a good natural and cultural environment rich in biological diversity, as a basis for health, quality of life and well-being. The following outcomes connected with conservation of forest genetic resources are intended to be achieved within a generation:

- Actions by central and local government to conserve biological diversity will be undertaken from a landscape perspective on ecosystem management. The buffering capacity of ecosystems – their ability to cope with change and undergo further development so that they can continue to be productive and deliver goods and services – will be maintained.
- Habitats will exist in sufficient numbers to maintain long-term viable species populations (favorable conservation status).

6 http://www.miljomal.nu/Environmental-Objectives-Portal/12-Sustainable-Forests/

7 http://www.miljomal.nu/Environmental-Objectives-Portal/16-A-Rich-Diversity-of-Plant-and-Animal-Life/

- Where important habitat types have been damaged, these will be restored, significantly improving conditions for biological diversity. Examples include habitat types that have shrunk substantially in area and/or distribution, whose quality as habitats has been generally degraded, or which support large numbers of species or genetically distinctive populations.
- Nationwide distribution of animal and plant species within, for example, their natural ranges will ensure sufficient genetic variation within and between populations.
- Sweden will play an active part in international environmental cooperation aimed at conserving biological diversity.

This objective will be very difficult or not possible to achieve by 2020, even if further action is taken. No clear trend in the state of the environment can be seen.

1.4. Forest protection and threats

1.4.1. Forest protection

The Swedish model for protecting forest biodiversity is a combination of general conservation considerations in all day-to-day management and the designation of protected forest areas. According to statistics by the Swedish Forest Agency, National parks and nature reserves together comprise 4.2 million hectares (10.4 million acres), which corresponds to roughly ten percent of Sweden's total land area. Of that amount, 793 000 hectares consist of legally protected forest land. In addition, habitat protection areas account for more than 21,000 hectares and nature conservation agreements account for more than 30 000 hectares. Over 47 000 hectares in the habitat protection areas and nature conservation agreements are productive forest land. Voluntary conservation areas comprise another 1.2 million hectares. In addition, about 4.5 million hectares of improductive forest land outside formally protected areas are exempted from forestry.

The number of key habitats registered with the Swedish Forest Agency is approximately 82 000, comprising a total area of about 380 000 ha. For some ownership categories, only a portion of key habits are represented in these statistics. On small-scale forestry holdings, some 50 000 key habitats, are registered with the Swedish Forest Agency. They comprise a total of approximately 158 000 ha, of which 133 000 ha are productive forest land. That corresponds to some 1.1 % of all productive forest land within the category of small-scale forestry.

1.4.2. Dead wood

The volume dead wood in Swedish forest is a well established indicator of biodiversity[8]. Many species are dependent on dead wood in different stages of decay. The absence of dead wood has been identified as the most important threat to already endangered species in Swedish forests[9]. Dead wood is distributed over the whole country the highest volumes are seen below the alpine region in northern Sweden. High volumes are also seen in Central Northern Sweden and on the west coast. Volume dead wood decreases in two general patterns, one southerly and one easterly. The average volume dead wood for Sweden is 8.1 cubic meters per hectare. Large differences can be seen for forest land within and outside of protected areas with 23.4 and 7.1 cubic meters per hectare, respectively.

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8 Den levande döda veden - bevarande och nyskapande i naturen. In Swedish. Samuelsson, J och Ingelög, T. 1996. ISBN 91-88506-07-X

9 Swedish Species Information Center, 2000

The volume of hard deadwood on productive forest land has increased with a magnitude of 50-70 % since year 1998. The total area of old forest has increased with 25-45 % since 1998, and the total area of mature forest with a large deciduous component have increased with 5-20 %, also since year 1998. The general trend for hard deadwood, old forest and mature forest with a large deciduous component has been positive. However, it is not certain whether there has been an increase or a decrease since year 1998 in the total area of thicket-stage and young forest dominated by broad-leaved species.

1.4.3. The Swedish Red List[10]

The official Swedish Red List is is a list of Sweden’s threatened species which describes current status, threats and trends in the species population. The Swedish Species Information Centre at the Swedish University of Agricultural Sciences is responsible for the Red List. In the Red List, every species is described with Red List Category and their occurrence in different administrative provinces. The Red List is updated every five years.

The Red List is a central foundation for planning for nature conservation. It is also an important barometer both in the Swedish environmental quality objectives (section 1.3.) and in international agreements such as the 2010 goal. According to one of the UN millennium developmental goals, the principles of sustainable development should be integrated into country policies and programs to reverse the loss of environmental resources. Another target is to significantly reduce the rate of loss of biodiversity by 2010. One of the indicators to measure the achievement of this goal is by using the index of the Red List.

More than half of the 4 126 redlisted species in Sweden are forest dwellers. Redlisted minor forest trees are *Ulmus minor* (Red List category “Near Threatened”), *Ulmus glabra* and *U. laevis* (“Vulnurable”), *Tilia platyphyllos* (“Critically Endangered”) and *Fraxinus excelsior* (“Vulnurable”). *Ulmus glabra* and *Fraxinus excelsior* are common in Sweden but are still redlisted. Population numbers and sizes in *Ulmus glabra* are decreasing due to the serious infections of Dutch elm disease. Similarly, *Fraxinus excelsior* is seriously affected by *Chalara fraxinea*, the fungi involved in elm disease.

1.4.4. Forest damage

Forest damage data has been collected since 1984 by the Swedish NFI and also within the European cooperation program, ICP Forests. A key variable used in monitoring forest health is defoliation. The types of forest damage included are those which are most common or cause most damage to Sweden's forests. In total, over 20 different types of forest damage are registered including fire, climatic damage, elk browsing, deer browsing, other cervidae browsers, beaver, small rodents, *Tomicus* sp., spruce bark beetle, other bark beetle, defoliators, resin top disease, decay or canker fungi, Scleroderris canker (caused by the fungus *Gremmeniella abietina*), needle cast fungi, needle rust fungi and pine twisting rust. The area of forest and other wooded land affected by abiotic, biotic and human induced damage is shown in Table 4.

The extent of damage from browsing elk (Am. moose) has been assessed since 2003. It appears to be a decrease in browsing of *Pinus sylvestris* throughout Sweden. However, nearly half of the *Pinus sylvestris* inventoried during 2004-2008 were affected by elk browsing.

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10 http://www.artdata.slu.se/rodlista

Monitoring of forest damage for 2009-2010 is part of a project within EU Life+ program (FutMon). The project aims to create a coordinated damage monitoring network at national, regional and EU levels by linking established monitoring projects with new monitoring methods.

Defoliation in *Pinus sylvestris* and *Picea abies* is presented annually in the NFI publication “Skogsdata”. Regular reporting and monitoring of the forest condition has lead to a more comprehensive view of forest damage and the identification of areas at risk of substantial forest dieback. The proportion of trees with needle loss has increased significantly since the middle of the 1980's, but has been stable for the last 10-15 years. In more recent years, outbreaks of spruce bark beetle have been prominent in southern Sweden. This is in connection with the serve storms of 2005 and 2007.

During 2009, a decline in the number of trees affected by spruce bark beetle was seen which indicates a decline in their population. This situation can however change rapidly with new storms or long warm summers. Other significant regional outbreaks are for resintop disease in young *Pinus sylvestris* in northern Sweden and *Chalara fraxinea* fungus in *Fraxinus exelsior* in southern Sweden. Both these outbreaks have been followed up with extra regional surveys by the Swedish University of Agricultural Sciences within the framework of their environmental monitoring and assessment.

Table 4. Forest and other wooded land with damage, classified by primary damaging agent (abiotic, biotic and human induced) and by forest type. Source : The Swedish National Forest Inventory and Sweden´s contribution to the Global Forest Resources Assessment in 2010 (FRA 2010, Pan-European indicator 2.4). na = data not available.

Category	**Year**	**Area damaged by different agents**						**Area primarily damaged by fire**	
		Total area	Primarily damaged by biotic agents		Damage primarily human induced		Primarily damaged by abiotic agents		
			Insects and disease	Wildlife and browsing	Forest operations	Other	Storm, wind, snow, etc.		
		1000 ha						1000 ha	No. of fires
Forest	2005	3498	381	1777	90	17	1233	1,61	643
	2000	1640	338	654	90	17	541	0,59	529
	1990	1478	207	611	90	17	553	na	na
Other wooded land	2005	na	na	na	na	na	na	0.58	1936
	2000	na	na	na	na	na	na	0.29	1752
	1990	na	na	na	na	na	na	na	na
Total forest and other wooded land	2005	na	na	na	na	na	na	na	na
	2000	na	na	na	na	na	na	na	na
	1990	na	na	na	na	na	na	na	na

Major storms in 2005 and 2007 caused severe wind throws in southern Sweden. These resulted in increased populations of some insects, notably *Ips typhografus*, affecting on average 1.8 % hectares of especially middle-age and old *Picea abies* stands. No credible trend can be seen for annual average area damaged by all agents and the agent primarily damaged by insects and disease due to the large storm fellings. In 2003, there was a large outbreak of *Gremminiella spp*, affecting on average 48.4 % of *Pinus sylvestris*. This species was also exposed to *Periderum spp*, with on average 3.3 % hectares damaged.

1.4.5. Genetic variation and erosion

Genetic erosion is a process whereby an already limited gene pool of an endangered species diminishes further as a result of die off of individuals before mating. Low genetic diversity in a population can cause reduced biological fitness and an increased chance of extinction due to inbreeding and random genetic drift. The smaller the populations are the more magnified the effect of genetic erosion becomes when each surviving individual of the species is lost.

Few scientific studies have analyzed the amount and structuring of genetic variation within and between natural populations of forest trees, especially in minor forest species. Assessments of genetic erosion are even more uncommon. Loss of genetic variation, both in number of alleles and levels of heterozygosity, especially in major forestry species can nevertheless be expected. The reasons include fragmentation of landscapes, regeneration with bred forest reproductive material and forest damage. The main loss of genetic variation is expected when using only one or a few clones in forestry. Clonal forestry is however still relatively unusual in Sweden.

Levels and rates of genetic erosion in *Picea abies* and *Pinus sylvestris* are unknown due to the absence of analysis on previous and present amounts of genetic diversity in forest stands of these species. This is also the case in *Ulmus* and *Fraxinus* which are severely threatened by forest damage, genetic diversity is presumably lost at a high rate within and across populations.

Obviously, there is a need to enhance the knowledge about genetic diversity within natural and domesticated populations for a majority of the forest trees. This issue is discussed further in section 5.4.

Chapter 2: The State of *In Situ* Genetic Conservation

2.1. Current *in situ* (on site) conservation of forest trees

In situ (on site or in place) conservation includes the continuing maintenance of a population within the environment where it originally evolved, and to which it assumingly is adapted[11]. *In situ* conservation is applied most frequently to wild populations regenerated naturally in protected areas or in managed forests, but can include artificial regeneration whenever planting or sowing is carried out, without directional selection, in the same area where the seed was collected[12].

The pan-European collaboration program EUFGIS (European Forest Genetic Information System)[13] has developed an online information system and a documentation platform for the inventories of forest genetic resources in Europe. One objective is to support the countries in their efforts to implement gene conservation of forest trees as part of sustainable forest management. The EUFGIS Portal[14] provides geo-referenced data on dynamic conservation units of forest genetic resources in Europe.

Presently the EUFGIS database contains data on 2 360 units for about 106 tree species in 31 countries. The units harbor a total of 3 139 tree populations. As one of very few European countries, Sweden has hitherto very few *in situ* genetic resources for the approximately 30 native forest trees to enter into the EUFGIS Portal. Obviously, there is a clear need to improve the *in situ* conservation of forest genetic resources in Sweden.

2.2. Future *in situ* conservation of forest trees

2.2.1. An increased need of forest gene conservation

A number of factors call for an increased *in situ* conservation of forest trees in Sweden. These include the effects of climate change, forest damage and increased forestry production.

According to the Intergovernmental Panel on Climate Change (IPCC), climate change will increase the average temperatures until 2100 and regional and seasonal patterns of precipitation will change considerably. Climate change will alter the environmental conditions that forest trees are adapting to and increase the frequency of extreme weather events. This for instance may include a shift in the range of forest trees, local extinctions of tree populations as a result of fragmentation and lack of reproduction, differences in migration rates due to latitude and the species biological characteristics, the introduction and further spread of pests and other (invasive) species, and a changed behavior of pollinators and species spreading seeds[15].

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11 Frankel, O.H. 1976. Natural variation and its conservation. Pp. 21–44 *in* Genetic diversity in plants (A. Muhammed, R. Aksel and R.C. von Borstel, eds.) Plenum Press, New York, USA.

12 FAO, FLD, IPGRI. 2004. Forest genetic resources conservation and management. Vol. 1: Overview, concepts and some systematic approaches. International Plant Genetic Resources Institute, Rome, Italy. ISBN 92-9043-648-4

13 http://www.eufgis.org/

14 http://portal.eufgis.org/

15 Koskela, J., Buck, A. & Teissier du Cros (Eds.). 2007. Climate change and forest genetic diversity - Implications for sustainable forest management in Europe. Bioversity International, Italy. ISBN 978-92-9043-749-9.

Another incentive to gene conservation is that several native forest trees occur in Sweden with their northern marginal populations. *Acer campestre*, *Carpinus betulus*, *Fagus sylvatica*, *Prunus avium*, *Quercus petraea, Sorbus intermedia*, *Taxus baccata, Tilia plathyphyllos, Ulmus laevis* and *Ulmus minor* exemplify such species. Swedish populations of these trees may likely possess unique alleles as a consequence of the species immigration history[16]. Also differences in climatic conditions contribute to different local adaptations and bring about genetically distinct populations or a clinal differentiation in outcrossed tree species.

The Swedish government emphasized in its proposition 2007/08:108 that an increase in forest growth should be promoted within the frame of the equal production and environmental objectives in the forest policy. A more intensive forestry, the use of alien tree species and clonal forestry are some alternatives under investigation in order to increase forest growth. To keep the balance between production and environmental objectives, this should infer increased efforts also for gene conservation.

Existing improvement programs for native trees at the Swedish Forest Research Institute include *Pinus sylvestris*, *Picea abies* and *Betula pendula*, forest species with vast distributions and tree numbers and with a high within and between population genetic diversity. The objectives of the breeding program include both improvement of economic tree performance, preparation for climatic change and management of the gene resource (conservation). The experimental design is to use a multiple population breeding system: by crossing, testing and selection, trees are bred to adapt to different adaptation profiles (combinations of latitude and temperature conditions) even outside present climatic conditions and geographic areas and to prepare for future climatic and environmental changes[17, 18].

Genetic variation from autochthonous provenances gives the opportunity of future selection and development. Certain alleles may prove important for tree growth, vitality, fiber quality or phenology, and could therefore be incorporated in future breeding programs. In the end, a high quality forest reproductive material may be produced. Nevertheless, forest tree breeding may in the long run result in a decreased genetic variation in the production forest. Even though single stands may have a somewhat higher genetic variation, genetic diversity will likely on the landscape level be lower than in conspecific natural populations.

2.2.2. Future strategy for forest gene conservation

Genetic variation is a prerequisite for a species´ long term survival and reproduction in a changing environment. Genetic variation is dynamic and changes over time. For that reason, existing genes should not be “frozen” but be a foundation for future population genetic variation.

These ideas were developed by Professor Gene Namkoong. During a number of years, Professor Namkoong was a member of the FAO panel of experts on forest genetic resources and of the Board of the International Plant Genetic Resources Institute. In 1994, Gene Namkoong was awarded the prestigious Marcus Wallenberg prize[19], for his ”… *path breaking contributions to quantitative and population genetics, tree breeding and management of genetic resources which*

16 Lönn, M., Leskinen, E. & Pamilo, P. 1998. Genetisk särprägel hos Svenska populationer av växter och djur. En kunskapsöversikt för naturvårdsändamål. Naturvårdsverket Rapport 4848. ISBN 91-620-4848-1. In Swedish.

17 Dynamic gene conservation for uncertain futures. Eriksson, G., Namkoong, E. and Roberds, JH. 1993. Forest Ecology and Management. 62: 15-37.

18 Danell Ö. 1993. Breeding programs in Sweden. 1. General approach. In: SJ Lee (ed) Progeny Testing and Breeding Strategies, Proc Nordic Group of Tree Breeding, Oct, Edinburgh, Forestry Commission, UK, pp 128(i)–128(v).

19 The Marcus Wallenberg Foundation for Promoting Scientific Research in the Forest Industry

form a solid scientific basis for the maintenance of biological diversity in forests all over the world".

When receiving the Marcus Wallenberg prize, Professore Namkoong expressed the following words:

... the existing gene bank is not a constant and given resource. It constitutes a dynamic changing system in which some genes die out, others remain and new ones are added. Some species have a high degree of genetic variation, others a low. The natural development is the driving force for genetic and ecological change. This natural system can be handled and conserved. Instead of trying to maintain a certain stage in the natural dynamic development, conservation should be directed to maintain the dynamics in the process of change and to make use of this.

The kind of dynamic forest gene conservation Professor Namkoong referred to is possible to achieve in Sweden in *in situ* in protected areas[20]. This strategy allows dynamic gene conservation of several tree species as well as of their associated species in their natural environment[21]. Also, simultaneous conservation of ecological, aesthetical, ethical and cultural heritage values are enabled.

Sections 2.2.4 and 2.2.5 describe a future resource efficient strategy for Sweden for gene conservation for one or several tree species in two types of protected areas: habitat protection areas and Ecoparks. These areas are widely geographically spread into a large number of different habitat types and forests which differ in age. Forestry has not been undertaken for a long and continuous time. The stands consequently are autochthonous, not bred or introduced and naturally regenerated. Furthermore, forestry is prohibited if conservation values are threatened. Nature conservation management may be used to conserve or to increase biodiversity and regeneration.

2.2.3. Knowledge required for in situ gene conservation

The knowledge about the amounts and distribution of genetic variation within and between natural populations of most species, including forest trees, is in general very low. Limited human and economic resources do not allow quantitative genetic and / or molecular analyses to be conducted in order to identify the most genetically unique populations with a high value for conservation. For these reasons, a future Swedish strategy for forest gene conservation must be practical and sustainable. This is possible by basing gene conservation on relevant major principles and conceptions which have originated from existing empirical and theoretical data on genetic variation in plant species[22]. These principles depend on the biological characteristics of the species to be conserved. Examples of such characters are the species population size, its geographic distribution range, the pollination mechanism, outcrossing rates and its sexual and / or asexual mode of reproduction.

EUFGIS[23] has developed applicable guidelines for countries to utilize in order to encompass a sufficient number of individuals per tree species and gene resource

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20 Dynamic gene conservation for uncertain futures. Eriksson, G., Namkoong, E. and Roberds, JH. 1993. Forest Ecology and Management. 62: 15-37.

21Eriksson, E., Ekberg, I. & Clapham, D. 2006. An introduction to forest genetics. 2nd ed. SLU. ISBN 91-576-7190-7.

22 White, T. L., Adams, W. T. & Neale, D. B. (Eds.). 2007. Within population variation; Geographic variation. Chapters 7 and 8, pages 149-229 in Forest genetics. ISBN 978-0-85199-083-5.

23 http://www.eufgis.org/outputs.html

(gene conservation unit) for sustainable gene conservation. These guidelines are certainly valuable also for the future gene conservation in Sweden. The following recommendations are given:

- 500 trees per gene conservation unit are sufficient for species with large and continuous populations which are extensively used in forestry. These species are subjected to extensive forest tree breeding and import of forest reproductive material. In Sweden, *Pinus sylvestris*, *Picea abies* and perhaps also *Betula pendula* and *Betula pubescens* belong to this category of tree species.
- 50 trees per gene conservation unit are sufficient for species with populations of varying size and structures and with no or limited use in forestry. In Sweden, several tree species such as *Acer platanoides*, *Alnus glutinosa, Alnus incana*, *Fagus sylvatica*, *Fraxinus excelsior*, *Populus tremula*, *Quercus petrea, Quercus robur, Salix caprea*, *Sorbus aucuparia*, *Tilia cordata,* and *Ulmus glabra* likely belong to this category.
- 15 trees per gene conservation unit are sufficient for species with (very) small and isolated populations, which may be situated in the edge of the species geographic distribution area. These species may be redlisted or their populations have recently decreased due to forest damage. In Sweden, for instance *Acer campestre, Carpinus betulus, Juniperus communis*, *Prunus avium, Sorbus intermedia*, *Taxus baccata, Ulmus laevis* and *Ulmus minor* belong to this category of tree species.

2.2.4. Habitat protection areas[24]

Environments that are important for plants and animals can often only be found as relatively isolated islands in a more ordinary landscape. The Swedish legislation makes it possible to set aside these kinds of areas as "habitat protection areas". The Swedish Forest Agency is responsible for this kind of protection, when the habitats are situated on forest land.

The areas that can be classed as habitat protection areas are, according to the legislation, "small land or water areas that are important environments for threatened plants or animals, or especially important to protect for other reasons". In 2009, the total number of areas were 6 250 amounting to 19 400 hectares of productive forest area. The aim with creating habitat protection areas is to protect biodiversity. The most common size for the protected areas is two to ten hectares, but the areas may be up to 20 hectares in size. The law restricts operations or activities that can damage the natural values and the environment. Such activities include pre-commercial thinning, thinning and final felling, but also digging drainage ditches and construction of roads.

Habitat protection areas are protected perpetually and are marked out in the terrain. Land ownership and hunting rights are not affected by the decision. The land owner gets full compensation plus 25 % extra for the limitation in the management of the forest. The state compensates for the reduced value of the property. After they have been set aside, the habitat protection areas are managed just like nature reserves. This includes that the areas are controlled through field visits and that pre-commercial thinning and final cutting of selected trees sometimes are carried out to maintain high natural values.

24 http://www.skogsstyrelsen.se/en/AUTHORITY/Forest-and-environment/Site-protection/Habitat-protection-areas/

2.2.5. Ecoparks[25]

Sveaskog, the largest forest company in Sweden, owns 3.3 million hectares of productive forest land, which is 14 % of Sweden's total productive forest land. Sveaskog´s nature conservation strategy includes the ambition to focus on conservation on 20 % of the company´s productive forest land. 650 000 hectares are assigned to nature conservation land using production forests, nature conservation forests and Ecoparks.

Ecoparks are large, connected landscapes throughout Sweden with high biodiversity conservation and environmental protection ambitions. On average, they are approximately 5 000 hectares, and each has its own unique ecological characteristics. Sveaskog opened the first Ecopark in 2003 and has planned to open altogether 36 Ecoparks within a few years time. In total, the Ecoparks comprise 175 000 hectares of forest land, of which more than 100 000 hectares are protected through binding Ecopark agreements with the Swedish Forest Agency.

The ambition in an Ecopark is to preserve and develop a high level of environmental stewardship. The work is carried out in accordance with management plans formulated in cooperation with authorities, non-profit organizations, representatives in the reindeer breeding industry and others. The focus on preserving biodiversity results in management strategies that can involve burning or damming forests, clearing conifer forests to make room for new deciduous forests, and restoring old grazing lands.

2.2.6. Other types of protected areas useful for forest gene conservation

In addition to habitat protection areas and Ecoparks, some other types of protected areas may be suitable for forest gene conservation. These include nature conservation agreements and nature reserves.

Nature conservation agreements[26] are voluntary agreements between the Swedish Forest Agency and forest owners that are interested in nature conservation. The aim is to preserve, develop or to create areas with high values. The nature conservation agreements can be valid up to 50 years and the set-aside areas are included in Sweden's statistics for formally protected areas, as even this form of protection is considered to be long-term. The land owner receives economical compensation for the limitations in the management that the agreement results in. The County Administrative Board and Local Authorities can also sign nature conservation agreements with forest owners.

In 2009, the total number of agreements were 4 000 and corresponded to a total area of 27 000 hectares of productive forest land. Areas that are signed as nature conservation agreements are usually between three and 20 hectares with an average of six hectares, but they can, in a few cases, be as large as 100 hectares. Nature values are in focus for the nature conservation agreements, but cultural heritage values are also of high importance since many of the areas are situated on formerly cultivated land. Moreover, areas important for recreation are often protected through nature conservation agreements as these values often coincide with natural and cultural values.

25 http://www.sveaskog.se/Documents/Om%20Sveaskog/Best%c3%a4ll%20informationsmaterial/Ekoparksfolder_eng.pdf

26 http://www.skogsstyrelsen.se/en/AUTHORITY/Forest-and-environment/Site-protection/nature-conservation-agreement/

Another potentially suitable protected area for gene conservation are nature reserves[27]. Approximately 3 200 nature reserves exist in Sweden. Their total area is almost six times greater than that covered by national parks (four million hectare as compared to 0.7 million hectare). Nature reserves are established on the initiative of the County Administrative Board in the relevant county, although any of the 290 Swedish municipalities can also designate areas as nature reserves. Nature reserves can be established on land owned by the state, municipalities or private interests. In the latter case, compensation is paid for restrictions in land use or part-acquisition, but the most common approach is for the state or municipality to purchase the land before the reserve is created. The Swedish Environmental Protection Agency buys land, pays compensation, and gives grants to municipalities for protection of nature.

Experiences gained from forest gene conservation in Ecoparks and habitat protection areas will be valuable for future *in situ* conservation activities in nature conservation agreements and nature reserves.

2.3. Priorities and capacity-building needs for future *in situ* conservation actions

2.3.1. Amendment of legislation

Gene conservation in habitat protection areas likely requires some amendments in the regulation on habitat protection[28]. Moreover, the Swedish Forest Agency needs to update its general recommendation concerning habitat protection areas[29]. The Swedish Forest Agency and the Swedish Environmental Protection Agency may also need to update the national strategy for formal protection of forests[30]. No amendment of regulations is needed to achieve gene conservation in Ecoparks.

2.3.2. Further education and administrative handling

Internal governing documents and routines at the Swedish Forest Agency need updating to allow for gene conservation in habitat protection areas. These types of documents and instructions are required for the officers responsible for their work with habitat protection areas. Internal governing documents and routines ensure a clear communication and participation and give the responsible officers the theoretical background as well as practical tools for conducting dialogue concerning forest gene conservation. Responsible officers need for instance to identify suitable gene resource units in the habitat protection area. Also the forest owner of the habitat protection area needs information about the gene conservation unit(s) is her / his forest.

In addition, the management plan of the protected area must state the kind of nature conservation management needed to ensure the conservation and sufficient regeneration of the genetic resource. As concerns Ecoparks, appropriate gene conservation units for different tree species need to be selected. This requires a regular close cooperation between responsible officers for Ecoparks at the forest company Sveaskog and the Swedish Forest Agency.

27 http://www.naturvardsverket.se/en/In-English/Start/Nature-conservation-and-wildlife/Nature-conservation-and-species-protection/National-parks-and-other-ways-to-protect-nature/

28 Förordning (1998:1252) om områdesskydd enligt miljöbalken m.m.

29 Skogsstyrelsens allmänna råd (SKSFS 2000:1) till 7 kap 11 § miljöbalken (1998:808) och 6 § förordningen (1998:1252) om områdesskydd enligt miljöbalken m.m.

30 Nationell strategi för formellt skydd av skog, Naturvårdsverket och Skogsstyrelsen, 2005.

2.3.3. Resource needs

Clearly, personal and economic resources are needed to enable *in situ* gene conservation in protected areas in Sweden. There is also a very limited knowledge about gene conservation among officers involved in nature conservation in general at the competent authorities and organizations concerned. To enable gene conservation in protected areas administrated by the Country Administrative Boards (applies to nature reserves) or the Swedish National Environmental Protection agency (applies to national parks), elementary knowledge on gene conservation for the concerned administrator in duty is required.

No specific research priorities are identified for achieving *in situ* gene conservation in protected areas.

Chapter 3: The State of *Ex Situ* Genetic Conservation

3.1. Current state of *ex situ* (off site) forest gene conservation

Ex situ (off site) conservation of forest genetic resources include the conservation in stands, clonal archives, genebanks, arboreta, botanic gardens and seed vaults. In Sweden, *ex situ* conservation includes *Picea abies* and *Quercus robur* (Table 5). For *Picea abies*, the clonal archives amount to 3.2 hectares with 225 cuttings. For *Quercus robur*, four stands exist with altogether 513 different mother trees (139 are duplicates) in 8.5 hectares. Except for these archives and stands, no other conservation is carried out for any other forest tree species. Furthermore, no seeds, pollen, tissue or other reproductive material of forest trees is stored.

Table 5. Ex situ conservation stands of clones of Picea abies and families of Quercus robur in Sweden

Gene conservation unit	Species	Size (hectar)	Number of families	Number of clones
Bellinga,Ystad	*Quercus robur*	2.7	234	-
Tånnö, Jönköping	*Quercus robur*	1.8	140	-
Vibyholm, Nyköping	*Quercus robur*	2.0	139	-
Askeby, Linghem	*Quercus robur*	2.0	139	-
Svenljunga, Borås	*Picea abies*	1.5	-	64
Trollebo, Vetlanda	*Picea abies*	0.7	-	37
Skullebo, Linköping	*Picea abies*	1.0	-	124

3.2. Areas managed for seed production

The area managed for seed production of domestic tree species in 2010 is approximately 3 241 hectares (Table 6). The area in *Pinus sylvestris* is from natural regeneration, *Quercus* and *Ulmus* are planted known provenances, as are the stands of *Picea abies*. Generally, these areas were established from 1835 and onwards. The approximate tree numbers in the stands are not known. Given that these areas generally are less than five hectares, it seems likely that the appropriate minimum population size for gene resources as recommended by EUFGIS (section 2.2.3) are not met. Obviously these seed production areas have been established or managed for the purpose of seed production and not in such a way as to contribute long-term gene conservation.

A possible way to adjust the seed production areas to become functional gene resources, if desired, is to include in their strategy the aim to maintain and enhance their long-term evolutionary potential. This means that management measures and silvicultural techniques are applied, as needed, to favor genetic processes that maintain the long-term viability of the genetic resource. The monitoring of the stands should be carried out by visiting them regularly to observe that they still serve their purpose and that they have not been damaged. A comprehensive assessment of the seed production areas should ideally be carried out through systematic field inventories conducted every five or ten years.

There are no designated *ex situ* genetic resources of exotic species or long-term provenance trials which include the purpose of gene conservation in Sweden.

Table 6. Area (hectares) managed for seed production purposes of domestic tree species in Sweden in 2010. Note that the intention of these areas is not to function as gene resources.

Species	Area (ha) managed for seed production
Acer platanoides	5
Alnus glutinosa	108
Alnus incana	3
Betula pendula	162
Betula pubescens	76
Carpinus betulus	10
Fagus sylvatica	441
Fraxinus excelsior	42
Picea abies	369
Pinus sylvestris	1 406
Prunus avium	8
Quercus petraea	41
Quercus robur	531
Tilia cordata	74
Ulmus glabra	10
Ulmus laevis	1
Ulmus minor	14

3.3. Botanical gardens and arboreta

There are several arboreta and botanical gardens established in Sweden. The largest botanical gardens are situated in the big cities in Gothenburg, Lund, Stockholm, and Uppsala. The botanical gardens have to varying extent collections of native and introduced tree species. The activities in both botanical gardens and arboreta are directed primarily towards other aspects than conservation of genetic resources, for instance education and exhibitions. Each arboreta and botanic garden has its own profile, although common to all is the low number of individuals per tree species. Therefore, these *ex situ* collections are not particularly useful for conservation genetic purposes.

3.4. Priority and resource needs for *ex situ* conservation

A regional action by NordGen Forest is investigating the possibilities of long term storage facilities of seeds from forest trees at the Svalbard global seed vault. The main objectives are threefold: i) To conserve seed samples from natural populations collected at certain intervals to secure back-up storage for future monitoring of long-term changes in genetic diversity; ii) To conserve seed samples from different stages and generations of breeding populations or seed orchards to monitor changes in genetic diversity taking place during breeding operations; and iii) Conservation of back-up seed samples of threatened populations. Example of the third category is threatened populations of *Ulmus* and *Fraxinus excelsior* with severely decreasing population sizes and numbers due to forest damage.

The *ex situ* forest gene bank, described in section 3.1, exemplifies “static” gene conservation in which adaptation to a changing environment is not possible. Moreover, *ex situ* conservation does not give the synchronous conservation of species associated to the gene resource trees. For these reasons, the priority, and therefore where additional resources should be directed, is to improve the *in situ* conservation, as described in Chapter 2.

The situation of *in situ* and *ex situ* conservation and breeding of the major forest species is discussed in Chapter 4.

Chapter 4: The State of Use and Sustainable Management of Forest Genetic Resources

This chapter describes various aspects of the marketing of forest reproductive material and forest tree breeding in Sweden. Information in sections 4.2 to 4.5 are provided by the Forestry Research Institute of Sweden.

4.1. Marketing with forest reproductive material

The Council Directive 1999/105/EC regulates the marketing of forest reproductive material between member states within the European Union. The 1999/105/EC directive is implemented in the national regulation. Marketing of forest reproductive material is only permitted if the basic material has been approved in a member state. In Sweden, basic material is approved by the Swedish Forest Agency and is registered in "Rikslängden"[31]. Basic material in Sweden includes seed sources, stands, seed orchards, parents of families, clones and clonal mixtures (Table 7).

Table 7. Basic forest reproductive material of stands, seed orchards and clones and clonal mixtures for native and exotic tree species and artificial hybrids registered in Rikslängden and approved for marketing. Only species with more than one stand or seed orchard are listed below. The number refers to the existing number of stands, seed orchards, clones and clonal mixtures for each species, respectively. For instance, there are four stands of Acer platanoides in Rikslängden. The type of information which is given in Rikslängden for the basic material is listed. E = exotic species or artificial hybrid

Basic material	Species	Number	Information in Rikslängden
Stands (>1)	*Acer platanoides*	4	
	Acer pseudoplatanus (E)	4	
	Alnus glutinosa	35	
	Alnus incana	2	
	Betula pendula	49	
	Betula pubescens	14	
	Carpinus betulus	4	Category
	Fagus sylvatica	45	Region of provenance
	Fraxinus excelsior	25	Latitude
	Picea abies	5	Longitude
	Pinus contorta (E)	9	Altitude
	Pinus sylvestris	5	Areal (hectares)
	Prunus avium	2	Year of establishment
	Tilia cordata	17	
	Querqus petrea	8	
	Querqus robur	92	
	Querqus rubra (E)	4	
	Ulmus glabra	4	
	Ulmus minor	2	
Seed orchards (> 1)	*Alnus glutinosa*	3	
	Betula pendula	9	
	Fagus sylvatica	2	
	Larix eurolepis (E)	5	Category
	Larix leptolepis x sibirica (E)	4	Latitude
	Picea abies	37	Altitude and area of the seed orchard
	Pinus contorta (E)	13	Number and latitudinal origin of its clones
	Pinus sylvestris	112	
	Querqus robur	2	
	Tilia cordata	2	
Clones and clonal mixtures	*Populus tremula x tremuloides* (E)	6	Category
	Populus tremula	1	Number of clones (if clonal mixture)

31 http://www.skogsstyrelsen.se/sv/Aga-och-bruka/Lagen/Handelsregler/Rikslangden-och-National-List/

Basic forest reproductive material is also classified into the categories source identified, selected, qualified and tested depending on for instance different genetic requirements the material meets. For a species or sub-species, region of provenance is an area or group of areas with sufficiently uniform ecological conditions in which stands or seed sources show similar phenotypic or genetic characters. From 2008, Sweden is divided into five regions of provenance. These regions correspond to the source-identified basic material of "seed source" in Figure 4.

The National List[32] summarizes the forest reproductive material approved for marketing in Sweden. All member states within the EU have their own National List, aiming to facilitate the marketing of forest reproductive material within the EU. The National List is accessible for the EU-commission and for all member states.

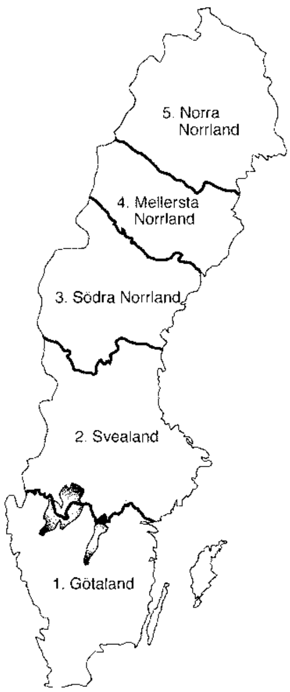

Figure 4. Five regions of provenance in Sweden as decided by the Swedish Forest Agency: 1. Götaland (latitude 55°- 59°, longitude 11°- 19°, areal 9 738 000 ha); 2. Svealand (lat. 58°- 62°, long. 12°- 19°, areal 1 029 000 ha); 3. Södra Norrland (lat. 61°-65°, long. 12°- 19°, areal 7 719 000 ha); 4. Mellersta Norrland (lat. 63°- 66°, long. 14°- 21°, areal 5 927 000 ha); and 5. Norra Norrland (lat. 65°- 69°, long. 15°- 24°, areal 10 603 000 ha).

The Swedish Forest Agency issues master certificates and approves import of forest reproductive material from countries within the EU and with countries outside the EU. Marketing with countries outside the EU is made possible by the enrollment to the OECD scheme for marketing with forest reproductive material. Furthermore, marketing takes place also with some additional countries which is made possible by the EU Commissions decisions on the equivalence of material from certain countries outside the EU with the forest reproductive material regulated by the council directive 1999/105/EU.

32 http://www.skogsstyrelsen.se/Global/aga-och-bruka/Lagen/nationallist.pdf

Concerning plant production in Sweden, approximately 300 to 380 millions of plants have been produced between 1998 and 2010 (Table 8).

Table 8. Total number of million plants produced between 1998 and 2010 in Sweden, the EU or within third countries belonging to the OECD-scheme for marketing with forest reproductive material. "Other conifers" include mainly Pinus contorta, but also Larix decidua, Larix kaempferi, Picea sitchensis and Pseudotsuga menziesii. "Broadleaves" mainly include Acer platanoides, Alnus glutinosa, Betula pendula, Betula pubescens, Fagus sylvatica, Fraxinus excelsior, Querqus petrea and Querqus robur. Figures for a few, small plant nurseries are missing for 2006 - 2008. Source: The Swedish Forest Agency, 2010.

Year	**Tree species**				Total
	Pinus sylvestris	*Picea abies*	Other conifers	Broad-leaves	
	Millions of plants				
1998	139	188	10	2,8	339
1999	124	171	8	1,8	304
2000	125	187	11	2,9	326
2001	124	172	12	3,4	311
2002	115	172	10	2,8	301
2003	119	186	11	3,1	320
2004	126	188	11	2,4	327
2005	125	194	10	1,4	331
2006	117	199	12	2,7	332
2007	117	232	15	3,4	367
2008	127	236	18	3,0	383
2009	127	227	23	3,5	380
2010	124	219	22	2,9	368

4.2. Demand and supply of forest reproductive material

An investigation of current and future seed supply and demand in Sweden was recently published by the Forestry Research Institute of Sweden [33]. It is evident from this report that there is a shortage of genetically improved seed for *Picea abies*. The shortage results in reduced genetic gain in tree growth and adaptive traits. There is also a shortage because less improved seed orchards are not replaced fast enough by new seed orchards with more improved trees. One conclusion is therefore to continuously establish new seed orchards.

The investigation suggests a number of methods to enhance the production of improved seeds, both by stimulating flowering and by reducing seed damages. Vegetative propagation would in addition to reducing the deficit also increase the genetic gain. Finally it is suggested to plant fewer improved seedlings per hectare and fill up with unimproved nursery stock. Competition and silviculture will favor the improved trees.

33 http://www.skogforsk.se/PageFiles/63421/Bilaga%204%20Fr%C3%B6f%C3%B6rs%C3%B6rjningsanalys.pdf

4.3. Genetic improvement programs and their implementation

Forest tree species presently subjected to tree improvement programs are listed in Table 9. The main improvement objective according, for timber, pulpwood, fuel wood and non-wood products, is specified.

Table 9. Forest improvement programs mainly for native tree species with different objectives in Sweden. For all other species 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
Picea abies	X	X	
Pinus sylvestris	X	X	
Betula pendula	X	X	
Pinus contorta	X	X	
P. tremula x P. tremuloides	X	X	X
Poplar sp.		X	X
Acer platanoides	X		
Alnus glutinosa	X		
Betula pubescens	X	X	
Fagus sylvatica	X		
Fraxinus excelsior	X		
Prunus avium	X		
Querqus petrea	X		
Querqus robur	X		
Tilia cordata	X		

A single breeding population is generally the unit used for forest tree breeding. The numbers of such units vary among species. Breeding data for the four major forestry species in Sweden is presented in Table 10. The individual breeding populations for the major species can be seen as provenances. For instance, breeding is performed for 22 provenances of *Picea abies* and 24 provenances of *Pinus sylvestris*. Each single breeding population is initiated by 50-70 tested plus trees. The plus trees are selected from about 300-400 tested candidate trees, i.e. original plus trees phenotypically selected from natural forest in Sweden and in neighboring countries, and in Canada for *Pinus contorta*. The plus trees are then progeny tested. A single breeding population can be seen as a large provenance population. In each generation, about 25 000 progenies are generated from these approximately 50 trees and planted in five field experiments. After 15 - 20 years, a new set of 50 trees are selected to breed the next generation. An average breeding cycle is 25 years. The altogether 25 000 trees in field tests can alternatively be represented by approximately 2 000 clones, replicated with 10-15 rooted cuttings each.

Table 10. Information on numbers of breeding populations and initial plus trees for major forest species in Sweden. Data on numbers of field tests and controlled crosses is also presented. Source: The Forestry Research Institute of Sweden

Species	**Number of populations**	**Number of initial plus trees**	**Variance effective population size**	**Number of field tests per generation**	**Number of controlled crosses**
Picea abies	22	7 100 plus trees 18 400 clones	2 200	110	1 100
Pinus sylvestris	24	6 000	2 400	120	1 200
Betula pendula	7	1 300	700	28	350
Pinus contorta	13	1 300	1 300	65	950

Some data for the minor species on the number of plus trees, provenance and progeny trials, and clonal testing and development is given in Table 11. The individual breeding populations can be seen as provenances. Analyses are done on all breeding inventory data and pedigree information. Measurements include traits of resistance, growth and wood quality normally used to calculate breeding values combined with an index for the breeding objective.

The tree breeding program provides sustainable conservation and improvement of the commercial tree species. About 50 % of all *Picea abies* and 80 % of all *Pinus sylvestris* seedlings currently planted are genetically improved and these figures are increasing over time. This will enhance future growth by about 10 million cubic meters per year. The tree breeding program also provides the Swedish society with adaptation to climate change by selecting trees suitable for these changes in advance.

For minor species of less commercial value the breeding program provides increased knowledge, supply of suitable trees for mass propagation, a preparedness to act if called upon by forestry and society for any reason and limited gene conservation. In addition to experiments with native species there are a large number of provenance and progeny tests for a variety of exotic tree species of for instance *Abies*, *Larix*, *Picea*, *Pinus*, and *Psedotsuga*. Analysis by national economists shows that benefits from forest genetic resources are shared among landowners (tree growers), the forest industry and society[34].

Table 11. Data on plus trees, provenances and progeny trials for minor native tree species in Sweden. Poplar sp. are exotic. Source: The Forestry Research Institute of Sweden

Species	Plus trees*	Provenance trials		Progenies / Clones		
Scientific name	Number	No. of trials	Number of provenances	No. of trials	No. Of clones in test	No. of clones in archive or seed orchard
P. tremula x P. tremuloides	332			21	337	207
Poplar sp.	140			17	190	93
Acer platanoides	100				104	96
Alnus glutinosa	120			6	139	62
Betula pubescens	150			2	42	>55
Fagus sylvatica	35	2	69	2	32	32
Fraxinus excelsior	100					106
Prunus avium	100			2	100	100
Querqus petrea	62					
Querqus robur	150			2	38	94
Tilia cordata	100					100

** List number of plus trees if program is beginning and only first generation seed orchards have been established.*

34 Gong, P., Löfgren, K-G and Rosvall, O. 2010. CERE WP #12/2010. Economic Evaluation of Biotechnological Progress: The effect of changing management behavior.

4.4. Conditions concerning forest tree breeding activities

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. The forestry sector and the government negotiate a four year research and development program. Advisory groups with landowners represented influence the annual research and development programs.

Regarding information systems for the tree breeding programs and intraspecific genetic variation patterns, there is a large database with all inventory and pedigree data for *Pinus sylvestris, Pinus contorta*, *Picea abies* and *Betula pendula*. The database is associated with a tool for genetic analysis. Genetic variation of quantitative traits related to growth, wood characters and phenology measured in experiments is the key issue for analysis and the results provides knowledge on genetic parameters such as genetic variances and correlations.

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 Brunsberg). Two cold storages at these locations support the breeding program for long term storage of seeds mainly from the major forest trees.

The responsibility for funding the tree improvement programs has shifted over time, from governmental to more private funding. However, during the last years, climate change has motivated some additional government efforts to find strategies for sustainable supply of renewable resources.

Currently, the Forestry Research Institute of Sweden is increasing it contacts with North America, as a consequence of the increasing interest in planting North American tree species in Sweden.

4.5. The roles of forest genetic resources in meeting the current demands for forest products and services

Different measures are taken in order to meet the current demands for forest products and services in Sweden. The planting of selected provenances and genetically improved seedlings of *Pinus sylvestris* and *Picea abies* since 1970 is estimated to have increased current growth by 3-4 %. The planting of successively more superior regeneration material combined with shorter rotation age for *Pinus sylvestris* and *Picea abies* forests and the enhancement of logging techniques, are measures taken to meet the current demands of forest products.

To meet the expected demands in Sweden for forest products and services, the Forestry Research Institute of Sweden calculated that future annual growth will increase by about 9% or 10 million m^3. This estimate is calculated using seedlings from existing and planned seed orchards of *Pinus sylvestris* and *Picea abies*. By using a more efficient propagation technique, future growth increment is expected to be 12 million cubic meters. To plant genetically improved nursery stock is suggested as the greatest and most profitable growth enhancing method available when compared with all other means to enhance growth.

According to a recent review of the Swedish tree breeding program[35], future breeding objectives are influenced by the widening objectives of forest management. These include the anticipated need of forests to serve as a natural resource for new biomaterials, biochemicals and bioenergy. Future forests need

35 Review of the Swedish tree breeding program. www.skogforsk.se. Ola Rosvall (Ed.). ISBN:978-91-977649-6-4

also to deliver a number of fundamental environmental services. The existing traditional breeding traits chosen are of fundamental value and continue to be relevant, however increased efforts must be put on developing economic weights to improve the balance among traits for best genetic selection.

The review also suggests that for the main forestry species, the original number and size of unrelated breeding populations should be kept. For minor species with few breeding populations, two sub-lines should be considered. In order to respond to climate change, improvement of climate adaptation and adaptability needs to be more emphasized. This is performed by an appropriate field-test layout to evaluate the tree's response to climate gradients. The idea is that selected trees which tolerate spatial variation in climate characters are also likely to tolerate temporal changes. Furthermore, the breeding of broadleaved species is more for keeping options for future action in response to climate and market changes, than to satisfy the small current demand for reforestation material. Increased interest in biomass production has recently prompted a shift from breeding birch to selection and testing of hybrid aspen and poplars. Nevertheless, the total effort to be expended on breeding broadleaved species, as well as the priority among species, needs to be decided so that appropriate breeding plans can be developed.

4.6. Current and emerging technologies in forest tree breeding[36]

Molecular genetics, genomics and biotechnology are fast developing research areas, yet far from being applicable to operational tree breeding. In the future, genome-wide selection has potential to become a powerful tool in combination with conventional methods for selection. In addition to providing direct observations of DNA variation, current marker technology can for instance help in identifying relatives, such as determining paternity of individual trees raised from polycrosses or open pollination, establishing ancestral pedigrees for trees used in pair crosses, and estimating contamination rates in orchards. Marker technology for association to phenotype will require further development and greater cost efficiency to be of real interest for operational breeding, but this could be realized in the not-too-distant future. It is suggested to store a sample of DNA from all founders for future use, to allow for example the tracking of their genetic contribution over generations.

Genetic modification of trees of interest for Sweden belongs to the future. The lack of well-characterized gene constructs of commercial value rather than the technology itself makes it far from being applicable. In addition, there is a need for long-term field testing to evaluate all consequences, concerning commercial, environmental as well as social issues.

A promising application of biotechnology comes from somatic embryogenesis as a method for commercial tree nursery stock production of *Picea abies*. Its greatest future potential is to replace seed orchards for mass propagation of superior seed lots, rather than for propagation of superior clones. Somatic embryogenesis seedlings could thus reduce the time lag from breeding progress to forest plantation by about 15-20 years while maintaining genetic diversity at a high level in operational forest stands. Somatic embryogenesis technology will also facilitate clonal forestry if used instead of rooted cuttings for field testing in the breeding program. At present, somatic embryogenesis seedlings can be used as donor plants for subsequent propagation on a large scale by rooted cuttings. However, somatic embryogenesis technology itself is not yet sufficiently

36 Review of the Swedish tree breeding program. 2011. Ola Rosvall (Ed.). ISBN: 978-91-977649-6-4

developed to offer a cost-efficient alternative for large-scale deployment under Swedish conditions. In addition, growth and performance of somatic embryogenesis seedlings have not yet been verified in comparison with zygotic seedlings.

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

4.7. Political measures to enhance the use of hardwood genetic resources[37]

Forest owners can currently apply for different grants from the Swedish Forest Agency regarding woodland within an EU rural development program. One objective is to increase the area of woodland with hardwood species in Sweden. Hardwood stands are defined in accordance with the Swedish Forestry Act as stands with a minimum area of 0.5 hectare and where at least 70 % of the trees are deciduous. Moreover, a minimum of 50 % of the trees should include one or several of the native species *Acer platanoides, Carpinus betulus, Fagus sylvatica, Fraxinus excelsior, Prunus avium, Tilia plathyphyllos, Quercus robur* and *Ulmus glabra*.

Landowners can receive financial support for planting broad-leaved trees on land which do not already hold hardwood stands and for tending or thinning a mixed stand in order to create a hardwood stand. The costs resulting from soil scarification, fencing (including fencing material), seedlings and planting as well as the planning of tending or thinning in the field can be covered. Owners of a forest property or properties in southern and central Sweden can apply for the grant. Financial support can also be obtained for regeneration measures or tending in already existing hardwood stands.

Another type of grant partly covers costs related to regeneration and tending of woodland with hardwood species. According to the Swedish Forestry Act, hardwoods stands must remain as such after regeneration. The objective of the financial support program is to compensate forest owners for the increased costs due to regeneration with hardwood species instead of for example *Picea abies*.

Financial support is given for forest operations necessary for obtaining a successful regeneration after cutting and for tending juvenile stands. This includes soil scarification, fencing, planting and grass removal. Regeneration measures in existing hardwood stands are given higher priority than measures in damaged plantations established with the purpose to create hardwood woodland. An additional subsidy, co-financed by an EU program, aims to create a first generation hardwood stand or create a hardwood stand by tending and thinning in a mixed forest stand.

37 http://www.skogsstyrelsen.se/en/forestry/Forestry/Grants-and-subcidies/

Chapter 5:
The State of National Programs, Research, Education and Training

5.1. Policy and legal framework

A revised forest policy statement with a national scope exists since 2008 in Sweden[38]. There is also a national forest program in implementation. A specific forest law exists which was latest amended in 2008. No sub-national forest policy or forest law exists.

Genetic improvement programs and their implementation for the main forestry species are discussed in section 4.3. To some extent, gene conservation is carried out within these programs. No national program for gene conservation currently exists for the other forest trees.

5.2. Research and training in forest genetics and gene conservation

A research school in forest genetics and breeding was carried out between 2004 and 2011 at the Swedish University of Agricultural Sciences. The research school was held in cooperation with the Forestry Research Institute of Sweden and ten associated companies from the Swedish forest industry[39]. The overall aim was to train a new generation of researchers and specialists in forest genetics. A combination of new molecular techniques, quantitative genetics, and operational tree breeding formed the focus of the program in order to create a strong knowledge base with potential for both research and industrial applications. The integration of molecular and quantitative methods was a key component achieved by tailored PhD courses and research projects.

The establishment of global contacts and collaborations was encouraged within the research school. Leading international researchers were invited to lecture and the postgraduate students operated in research environments with strong international networks. The post-graduate students were registered at different departments of the Swedish University of Agricultural Sciences and at the University of Umeå. The students were employed by various forestry companies throughout the five year program. Four years were dedicated to PhD studies and research, while one year was set aside for applied research and development in cooperation with the host company.

The research school comprised eleven post graduate students, supervisors, management and operational resources together with linked positions as associated and guest professorships. Ten of the post graduate students have so far defended their doctor´s thesis. The research projects mainly involved different aspects of forest tree breeding: e.g. genetic markers, breeding value assessment, identification of genes involved in productivity, fiber quality, flowering time and resistance to root rot and biotic stress. One research project dealt with how evolutionary genetic factors influenced coancestry and genetic structure in natural forests. Currently, a continuation of the research school in forest genetics is planned.

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38 "A forestry policy in line with the times", http://www.sweden.gov.se/content/1/c6/10/84/52/670bceae.pdf
39 http://resschool.slu.se/

5.3. Education and training in forest genetics and gene conservation

Graduate education programs in genetics, biotechnology and forest tree breeding are of a high standard in Sweden. Genetics is taught at all major universities, although education in forest tree breeding is restricted to two of the universities. The entire educational programs and individual courses in these subjects are well established. Expertise in genetics, biotechnology, and forest tree breeding is thus good in Sweden. One difficulty however is the generally low interest from forestry students to attend a graduate program in forest genetics. One reason is that courses at the under graduate level have been too restricted. Currently there are plans and attempts to improve the under graduate courses, thereby increasing interest for post graduate studies.

The Swedish University of Agricultural Sciences conducts introductory and advanced training in for instance forest genetics and forest biotechnology within the Forestry master's program[40]. At the advanced level, also as separate master's programs and courses are given. Postgraduate studies in biology are offered, specializing in plant physiology, ecophysiology, plant molecular biology and forest genetics. According to data provided by Sweden to the Global Forest Resources Assessment 2010 (FRA 2010), 90 students had in 2008 a Master´s degree or equivalent in forest-related education including forest genetics. For Bachelor´s degree, the number was 31.

Although forest genetics is included is some master and post-graduate programs and education, focus is on biotechnology in forest production systems, functional plant genomics, plant biotechnology and molecular breeding. Thus, to a relatively small extent, conservation of forest genetic resources is treated in the forestry educations.

Within the master program some universities offer courses covering biodiversity and selection, plant breeding, comparative genetics, biotechnology issues and bioinformatics tools within the plant breeding area. The objectives in some course(s) may be to gain knowledge about the importance of genetic resources and plant breeding for sustainable and successful plant growing, genetic variation and gene erosion in horticultural plant species.

Moreover, courses are held in ecology and nature conservation including elementary theory about genetic resources and their conservation.

5.4. Priorities and needs

5.4.1. Information

The main challenges, needs and priorities for developing or enhancing the information management systems for forest genetic resources concerns the future planned activities for *in situ* gene conservation in the habitat protection areas and in Ecoparks, as described in section 2.3.2.

Concerning the use of forest genetic resources in forestry, forest owners, including single landowners to big enterprises, are to different extents aware of the roles and values of forest genetic resources of major tree species for a sustainable forestry. The significance of biodiversity on species and ecosystem levels are much more acknowledged than genetic variation, especially if the tree species is of limited importance for forestry.

40 www.upsc.se

Genetic diversity is of significant importance for the resilience in an ecosystem and to maintain viable populations of species. However, the knowledge about genetic diversity in general is very low and has received far less attention than biodiversity on the species and ecosystem levels. For that reason, the All Party Committee on Environmental Objectives proposed to the Swedish government that knowledge on genetic diversity of species used in forestry and agriculture and in natural populations claims an increased attention[41]. By 2015 at the latest, a survey and a monitoring of genetic diversity should be launched in order to formulate targeted aims and achievements concerning genetic diversity. Competent authorities should be responsible for reaching the interim target. At the time of writing, any further details concerning the above mentioned proposal are still unclear.

5.4.2. Research and education

No comprehensive inventory has been undertaken to study current levels of genetic variation in natural populations. However, some projects have started: For instance in *Pinus sylvestris,* genetic variation and levels of inbreeding are compared in natural and man-made stands, in which genetically improved stands are included. In the EU research project NovelTree, the Swedish Forest Research Institute and the Finnish Forest Research Institute (METLA) conduct a meta-analysis of *Pinus sylvestris*, where genetic variation and performance are explained by climatic indices used in climatic research. The objective is to produce common deployment functions and possibilities to predict performance in future climatic conditions. In addition, a research project is initiated to investigate the genetic variation among founder trees in the breeding program of *Picea abies*.

Regarding minor forest tree species, surveys and inventories of intraspecific genetic variation are still scarce. Evidently, there is a need to increase the knowledge on conservation of forest genetic resources in minor forest trees. This could likely be achieved by expanding gene conservation issues in relevant educational courses in operational forest tree breeding and quantitative genetics. The extensive national cooperation between the Swedish universities and the Swedish Forest Research Institute facilitates these kinds of research projects.

Currently, there are no scientific or technical approaches or mechanisms used for monitoring, preventing or correcting genetic erosion and vulnerability of forest trees. Moreover, Sweden has not undertaken any risk disaster analysis for forest genetic resources of other species than the main forestry species.

41 http://www.regeringen.se/content/1/c6/16/52/32/c4a15816.pdf

Chapter 6: The State of Regional and International Collaboration

6.1. Participation in international networks

Sweden participates in several international networks and activities associated with gene conservation and forest tree breeding (Table 12).

6.1.1. Forest gene conservation

NordGen Forest[42] serves as a Nordic meeting place to examine issues in the fields of forest genetics and genetic resources, supply of seeds and plants, and methods for regeneration. The main goal for NordGen Forest is to contribute to the establishment of the best possible Nordic forests for the future. NordGen Forest consists of two bodies, each with members from all Nordic countries: The Council members exchange information on regeneration issues, discuss different topics of interest for Nordic forestry and plan coming events. The Working Group on Genetic Resources ensures cooperation in conservation and use of forest genetic resources. NordGen Forest host thematic days, conferences, seminars and meetings, monitor and initiate research and development, and disseminate information in the above mentioned subject area.

Sweden also is a member of the European Forest Genetic Resources Program, EUFORGEN[43]. EUFORGEN is a collaborative program among European countries to promote conservation and sustainable use of forest genetic resources. It serves as a platform for pan-European collaboration in this area, bringing together scientists, managers, policy-makers and other stakeholders. EUFORGEN facilitates development of science-based strategies, methods and recommendations for policy-makers and managers to improve the management of genetic resources of forest trees in Europe. It also contributes to various initiatives and projects making available better information on forest genetic resources in Europe.

EUFORGEN was established in October 1994 as an implementation mechanism of Strasbourg Resolution S2 (Conservation of forest genetic resources) of the first Ministerial Conference on the Protection of Forests in Europe (MCPFE), held in France in 1990. The program also contributes to implementation of other MCPFE commitments on forest genetic resources and relevant decisions of the Convention on Biological Diversity. The EUFORGEN activities are funded by participating countries and carried out through working groups and networks. The EUFORGEN Steering Committee is composed of National Coordinators from all member countries and it has the overall responsibility of the program. The EUFORGEN Secretariat is hosted by Bioversity International.

6.1.2. Forest tree breeding

The Forestry Research Institute of Sweden has several collaboration breeding activities for the major forestry species: an exchange of breeding populations with Finland; taking part in a Nordic cooperation project (Adapt CAR); involvement in a network of geneticists within the EU called TREEBREEDEX[44]; participation in

42 http://www.nordgen.org/index.php/en/content/view/full/65

43 http://www.euforgen.org/about_euforgen.html

44 http://treebreedex.eu/

the EU research project “NovelTree”[45] and collaboration with the Australian breeding organizations STBA, Plantplan Genetics. The most operational cooperation is with Finland and with Australia. The participants in networks and the main functions and benefits that are derived from the networks regarding breeding activities for the major forestry species are listed in Table 13. With the Finnish Forest Research Institute (METLA), there is an exchange of plus trees, genetic tests and test data. Regarding a more informal global network for research in forest geneticists, Sweden collaborates mainly with North Carolina State University, USA; and a growing collaboration with the pacific Northwest of USA and Canada.

The tree breeding data management system at the Forestry Research Institute of Sweden is used to support a sustainable use of genetic resources. Also information on the TREEBREEDEX databases is provided. TREEBREEDEX is computerized with standard formats to facilitate data exchanges as has the tree breeding data management system, although it is not intended for open access.

Table 13. Overview of the Swedish participation and main activities carried out through (regional) networks for forest genetic resources

Network	Participants	Activities	Genus/species involved
NordGen Forest	Sweden, Norway, Finland, Denmark and Iceland	Information exchange. Establishment of genetic conservation strategies. Elaboration, submission and execution of joint (research) projects.	All tree species
EUFORGEN	26 European countries	Information exchanges. Development of technical guidelines and of shared databases. Establishment of genetic conservation strategies. Germplasm exchange. Elaboration, submission and execution of joint research projects.	All tree species
TREE-BREEDEX	European network for breeding and genetics organizations	Information exchanges. Development of common databases for genetic material of major species including all field experiments and the materials involved (provenances progenies clones	*Picea abies, Pinus sylvestris*
Adapt CAR	METLA, Finland. KVA, Denmark. Skog og Landskap, Norway. Iceland. Baltic organisations	Information exchanges. Elaboration, submission and execution of joint research projects.	*Picea abies, Pinus sylvestris*
Australia Plant Plan Genetics	Australia, Sweden	Data management tools	
NovelTree	Sweden, Finland, France, Italy, United Kingdom	Genetic improvement of composition and characteristics of forest products. Breeding strategies and species based guidelines	*Picea abies, Pinus sylvestris, Pinus pinaster, Populus spp*

6.2. International agreements

National and international laws, treaties, conventions, as well as trade agreements and agreements relevant to the sustainable use, development and conservation of forest genetic resources are listed in section 7.1.

45 http://www.noveltree.eu/

6.3. Needs and priorities to improve international collaboration

In general there seems to be no clear need or priority to improve international collaboration. For *in situ* and *ex situ* genetic conservation and management, there is already a valuable exchange of ideas within the international networks NordGen Forest and EUFORGEN.

Needs and priorities of developing the international collaboration for forest tree breeding are discussed in more detail in section 4.4. Awareness raising needs and priorities for forest genetic resources issues rather include the preparation of national targeted forest genetic resources information as described in section 2.3.2. Also the needs for enhancing training and education in order to improve understanding of benefits and values of forest genetic resources, is a national concern, as evident from section 5.4.

Chapter 7:
Access to Forest Genetic Resources and Sharing of Benefits Arising from their Use

7.1. Subscription to agreements relevant to genetic resources

Sweden has subscribed to several national and international laws and agreements which to various extents regulate genetic resources in general, in particular:

- The Swedish environmental code 1998:808.
- Plant breeders' rights in Sweden (1997:306) which also applies to forest genetic resources.
- The Kalmar Declaration (2003). A Nordic Ministerial Declaration on the access and rights to genetic resources in fisheries, agriculture, forestry and food.
- The seeds (national lists of varieties) regulation 1997:383 and the council directive 2100/94/EC on community plant variety rights. Not applicable to forest reproductive material.
- National regulations for agricultural and horticultural reproductive material: the marketing of seed and plant propagating material in regulation 1976:298 and 2000:1330, with its basis in EU-directives 1966/401/EU; 1996/402/EU and 2002/53-57/EU.
- The council directive 1999/105/EU and corresponding Commission decisions on the equivalence of forest reproductive material from certain countries outside the EU. Sweden has also national regulations for the marketing of forest reproductive material based on 1999/105/EU.
- The council directive 1998/44/EU regarding legal protection for biotechnological inventions in the Swedish patent law (1967:837).
- The Bonn guidelines on access to genetic resources and the fair and equitable sharing of the benefits arising from their utilization.
- The international union for the protection of new varieties of plants (UPOV). Note, there are still no protected varieties of forest reproductive material in Sweden.
- Trade Related aspects of Intellectual Property Rights (TRIPS).
- The Convention on Biological Diversity (CBD).
- The Convention on International Trade in Endangered Species of wild fauna and flora (CITES).
- The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

7.2. Access and benefit sharing (ABS) of genetic resources

7.2.1. General state of ABS on genetic resources

The access to genetic resources and sharing of benefits arising out of their use has remained about the same over the past ten years, however Sweden has included ITPGRFA in its national legislation[46, 47].

The environmental code[48] in Sweden imposes restrictions concerning area protection which includes plant genetic resources (Chapter 7), and rules out the special provisions concerning the protection of biological (not specifically genetic) resources of animals and plants (Chapter 8). It also deals with biological material, for instance the right to pick or take products from nature.

The penal code[49] chapter 12, "on crimes inflicting damage", refers to illegal collection of various biological materials: "*A person who in a forest or field unlawfully takes growing trees or grass or from growing trees takes twigs, branches, bark, leaves, bast, acorns, nuts or resin, or takes windfall trees, stone, gravel, sod or similar things not prepared for use, shall be sentenced for trespass if the crime is considered to be petty having regard to the value of what is taken and other circumstances*". Evidently acorns are mentioned, but not cones. Other products from nature, if not protected (such as cones) may be collected without need to compensate the landowner.

The Convention on Biological Diversity emphasizes that utilization of genetic resources to share a fair and equitable part with the provider country or the country of origin. The current Swedish Patent legislation[50] requires that the origin of the genetic resources used in an invention shall be disclosed in patent applications. If the origin is unknown it should be indicated. The failure to provide this information does not affect the handling of the patent application by the authorities or the rights conferred by a patent. The requirement does not have any material effects on e.g. the validity of granted patents. In the Nagoya Protocol, the importance of user country legislation is reflected in several articles (notably Articles 15 and 16). EU and its Member States have not yet ratified the Nagoya Protocol: a process including impact assessments, both on national and EU level, needs first to be finalized.

7.2.2. The Right of Public Access and access to biological material

Appreciation of forest values is deeply rooted in Sweden. One of the most popular outdoor activities is recreation in the forest, which is facilitated by The Right of Public Access.

The legal basis for The Right of Public Access is a constitutional practice or law[51]. Since 1994, it is a part of the Swedish Constitution, specifying this as a law being superior to other regular Acts[52]. The Right of Public Access is very strong standing in Sweden, however no statutes exactly define its scope, rather various other laws set limits as to what is allowed. The Environmental Act imposes the

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46 Regeringens proposition 2002/03:52. Det internationella fördraget om växtgenetiska resurser för livsmedel och jordbruk

47 Förordning (2011:474) om förenklat tillträde till växtgenetiska resurser

48 The Swedish Environmental Code: http://www.sweden.gov.se/content/1/c6/02/28/47/385ef12a.pdf

49 The penal code: http://www.sweden.gov.se/content/1/c6/02/28/47/385ef12a.pdf

48 Patentkungörelse 1967:838

51 www.naturvardsverket.se/sv/Att vara ute i naturen/ Allemansratten- en unik mojlighet/Vad ar allemansratten.

52 Regeringsformen 2 kap. 18 §: 'Alla skall ha tillgång till naturen enligt allemansrätten oberoende av vad som föreskrivits ovan. Lag (1994:1468)'.

obligation on those using The Right of Public Access to take due care. The Right of Public Access gives the public the right to for instance access, walk and cycle on any land except for private grounds and where such access itself may cause damage, for instance on land planted with crops. There are also restrictions concerning nature reserves and protected areas. The right to pick wildflowers, mushrooms and berries, provided they are not legally protected, is also included. The Right of Public Access does not concern access to genetic resources in particular.

7.3. Access and benefit sharing (ABS) of forest genetic resources

7.3.1. State of ABS of forest genetic resources

In a recently published report, the present situation regarding the access and rights to forest genetic resources in the Nordic countries was described[53]. The aims of the report were mainly to identify issues and developments in international law that could affect the present situation of ABS on forest genetic resources and to explore the legal status for breeding as a process and breeding materials with emphasis on patenting and recent developments in patent legislation.

The main finding in the report was that currently no problems or obstacles were identified as regards to ownership, access or exchange of forest genetic resources. At the time being, patents have neither been a strong incentive for the forest sector nor brought about any important obstacles for innovations in this field.

7.3.2. Patent protection of biotechnological methods

No protection of plant varieties currently exists in Sweden for trees used for forestry purposes. There are some examples of protection of varieties of horticultural trees, such as apple. Several product or process patents exist for genes involved in different traits of importance in agricultural crops. There are no process patents for forest genetic resources, however a Swedish company presently claims patent protection for a variety of biotechnical methods for regulating the expression of a few functionally characterized genes or polypeptides.

7.3.3. Forest tree breeding and ABS

As described in section 4.5, only traditional quantitative based forest tree breeding is conducted in Sweden. There is ongoing research using molecular techniques such as marker aided selection, however these techniques are under development and yet not used in commercial forestry.

Over the past ten years, the Forest Research Institute of Sweden has signed different agreements, for instance concerning germplasm exchange, in order to maintain or enhance the access to forest genetic resources outside the country. Following international agreements are concerned: i) With Finland regarding selection of Finnish plus trees of *Betula pendula* in order to increase the Swedish breeding population; ii) With Latvia regarding testing selected hybrid aspen clones for utilization in Sweden; iii) With Lithuania regarding testing selected *Alnus glutinosa* for utilization in Sweden; and iv) With Belgium regarding testing selected *Populus* clones for utilization in Sweden.

53 Seeking Appropriate Legislation Regulating Access and Exclusive Rights to Forest Genetic Resources in the Nordic Region. Morten Walløe Tvedt. Fridtjof Nansen Institutt. Report 9/2011. ISBN 978-82-7613-626-5.

7.3.4. Future perspectives on ABS of forest genetic resources

The Nagoya Protocol will likely not affect the substance of the regulatory framework as concerning the access to genetic resources. However, the Nagoya Protocol deals with an increased demand of clarifying which rules apply to those researchers or organizations who wish to gain access to genetic resources. For the parties involved, the Nagoya Protocol also aims at reviewing for instance the national legislation. This is to support the purpose of the Nagoya Protocol and to facilitate that benefit sharing is in accordance with what has been agreed upon between the country that has allowed access and the researcher / organization that utilize the genetic resource. A ratification of the Nagoya Protocol by Sweden will need some awareness also from the perspective of forest genetic resources.

Concerning patent applications, up to now only methods used in forest tree breeding activities have been involved and not the material itself, i.e. the gene sequences or gene expressions. As long as the genetic material is not subjected to patent protection, no complications in the exchange of forest genetic resources are expected.

Furthermore, patenting may not pose a practical threat to the access of forest genetic resources in the Nordic climate. The reason is that the patent protection period of 20 years would expire before the onset of seed production in most tree species of interest for the Swedish forestry. The future use of patenting could however be different for short rotation species, for instance Christmas trees and biofuel crops such as *Populus spp*.

Due to expected climate change, the marketing of forest reproductive material from southern countries may increase in a long-term perspective. In a situation with certain restrictions on access to forest genetic resources from countries in the south, access to forest genetic material may become complicated.

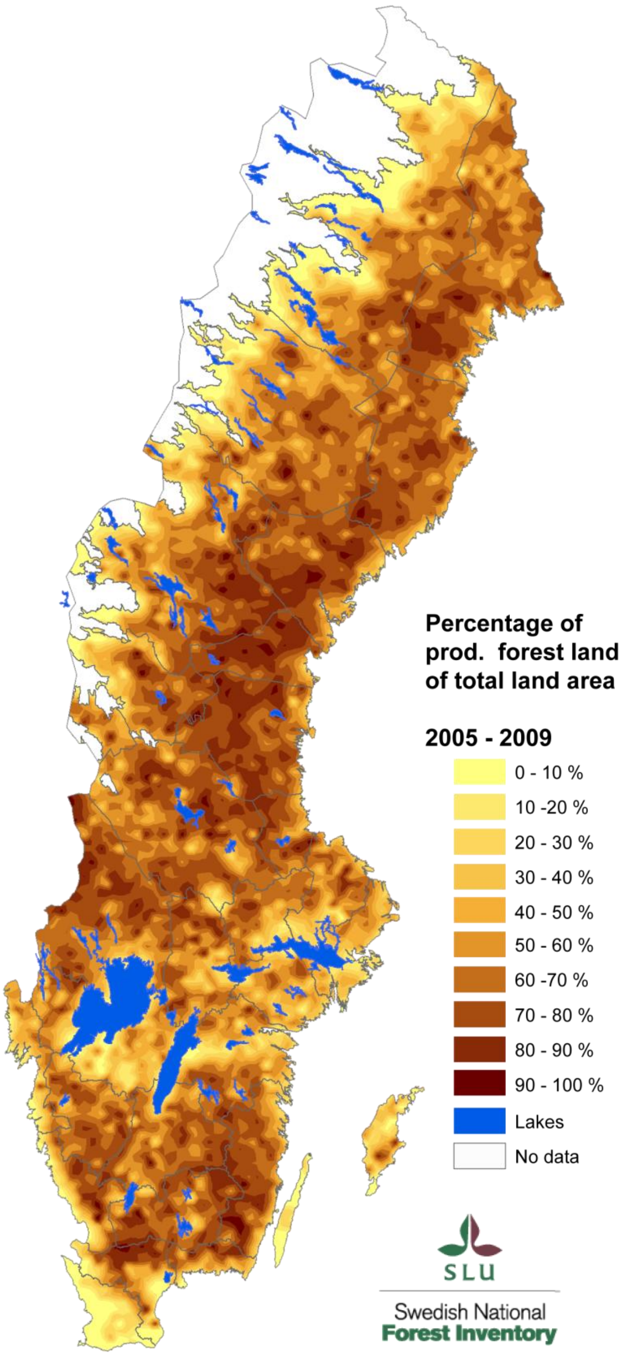
Patents on propagation methods using biotechnology such as somatic embryogenesis may become likely in the foreseeable future. Such commercial developments might require particular solutions to safeguard the presently smooth access and rights to forest genetic resources in the future.

Acknowledgements

I would like to thank Ola Rosvall at the Swedish Forest Research Institute for providing extensive information on forest tree breeding and related issues, Jonas Fridman at the Swedish National Forest Inventory for data of forests and forestry in Sweden, Bengt Andersson for valuable comments especially on education and forest tree breeding and Peter Bergman at Sveaskog for his open attitude towards forest gene conservation in Ecoparks. I am also thankful to colleagues at the Swedish Forest Agency and Ylva Tilander at the Ministry of Rural Affairs for suggesting improvements on this work. This report is dedicated to my former professor Gösta Eriksson, Swedish University of Agricultural Sciences, for influencing me with his enthusiasm and belief concerning a dynamic gene conservation of forest trees.

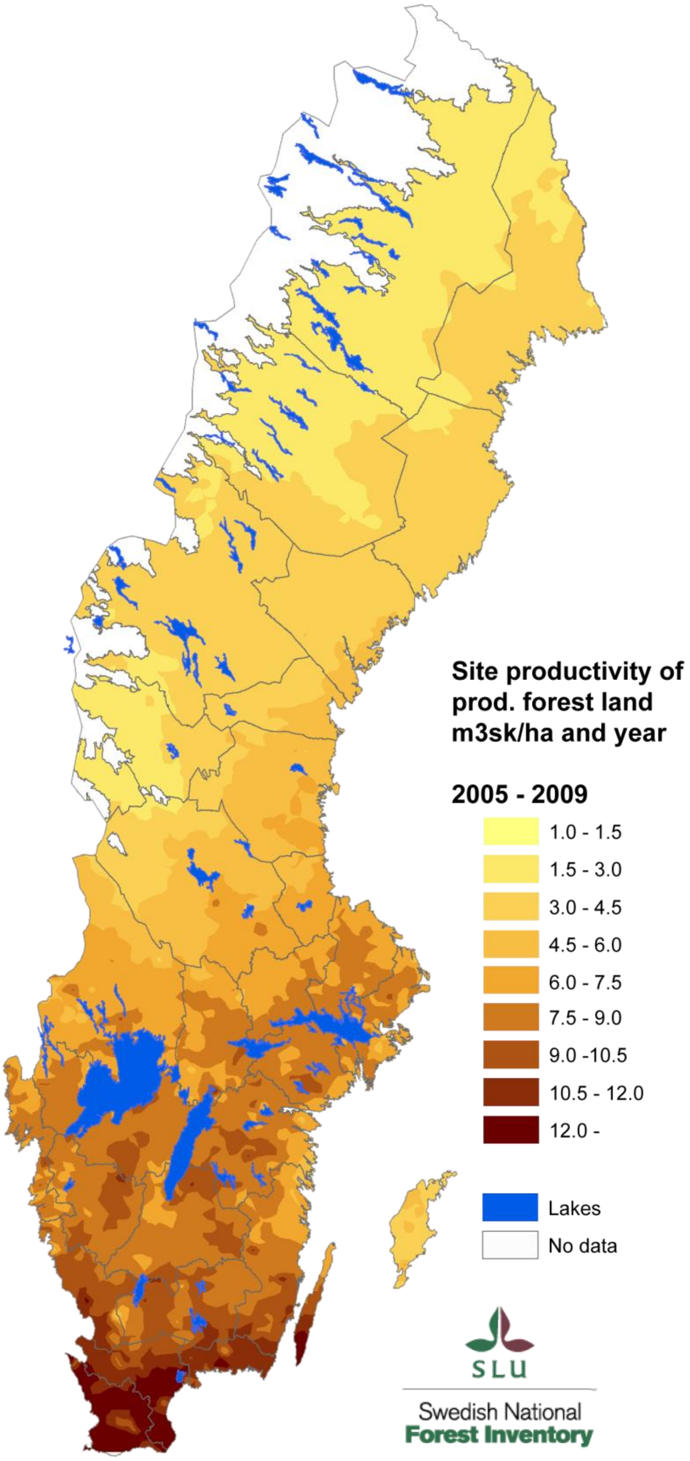
Annex I

Map 1. Proportion of productive forest land in Sweden. Source: The National Swedish Forest Inventory



Annex II

Map 2. Mean values of forest productivity (m^{3}sk per hectare and year) for the years 2005 - 2009 in Sweden. Source: The National Swedish Forest Inventory



Annex III

Map 3. Annual increment on productive forest land (m^3sk/ha and year) in Sweden. The data represents five year averages for the period 2004-2008. Source: The National Swedish Forest Inventory