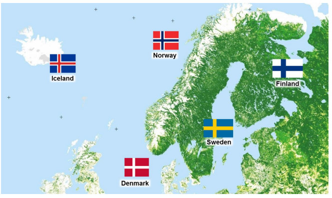


# Reforestation challenges in Scandinavia

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## Abstract

In the keynote, major reforestation challenges in Scandinavia will be highlighted. The following countries make up Scandinavia: Iceland, Norway, Sweden, Finland and Denmark. For Iceland, with only a forest cover of 2%, a major reforestation challenge is the deforestation and overgrazing in combination with land degradation and extensive soil erosion. The challenges include the conflicts with livestock farmers. For centuries the commons were used for sheep and horse grazing. However, more and more of farmer grazing land have been fenced up, allowing the regeneration of birch and plantations of other species to increase. With a forest cover of 37% and 69% respectively, for decades a major reforestation challenge in Norway and Sweden has been the risk of seedling damages from the pine weevil. Unprotected seedlings can have a survival rate of less than 25% after being planted. Pine weevils feed on the bark of planted young seedlings at regeneration sites. If the seedling is girdled, it will not survive. In Sweden, and soon in Norway, pesticides have been forbidden. In the keynote, new methods and technology will be presented based on non-chemical protection. In Finland, with a forest cover of 75%, a major reforestation challenge is linked to the forest structure. The structure of Finnish forestry includes many private forests in combination with small regeneration sites. This implies a situation where logistics and methods for lifting and field storage provide a major challenge in order to preserve seedling quality until the planting date. Due to this situation, new logistic systems and technologies are being developed in Finland, including new seedling cultivation programs (including cultivation under Light Emitting Diodes (LEDs)) to match the access of fresh planting stock to different planting dates. In Denmark, with a forest cover of 13%, a major reforestation challenge is the possibility of future plantations based on a wide range of relevant species. For this to become a realistic option, new methods and technology have to be developed in reforestation activities that support this possibility. These methods and technology should make it possible to not be limited to certain species due to problems and restrictions during field establishment. This due to the prospect of establishing stable, healthy, and productive stands of various forest species that can be adapted to future climate change.

## Keywords

Scandinavia, Reforestation Challenges, Deforestation, Degradation, Erosion, Pine Weevils, Lifting, Field Storage, Alternative Species, Climate Change

## Contents



# 1 Definition of Scandinavia

In my keynote, major reforestation challenges in Scandinavia will be highlighted. In Scandinavia, the following countries are included: Iceland, Norway, Sweden, Finland and Denmark (Fig. 1).

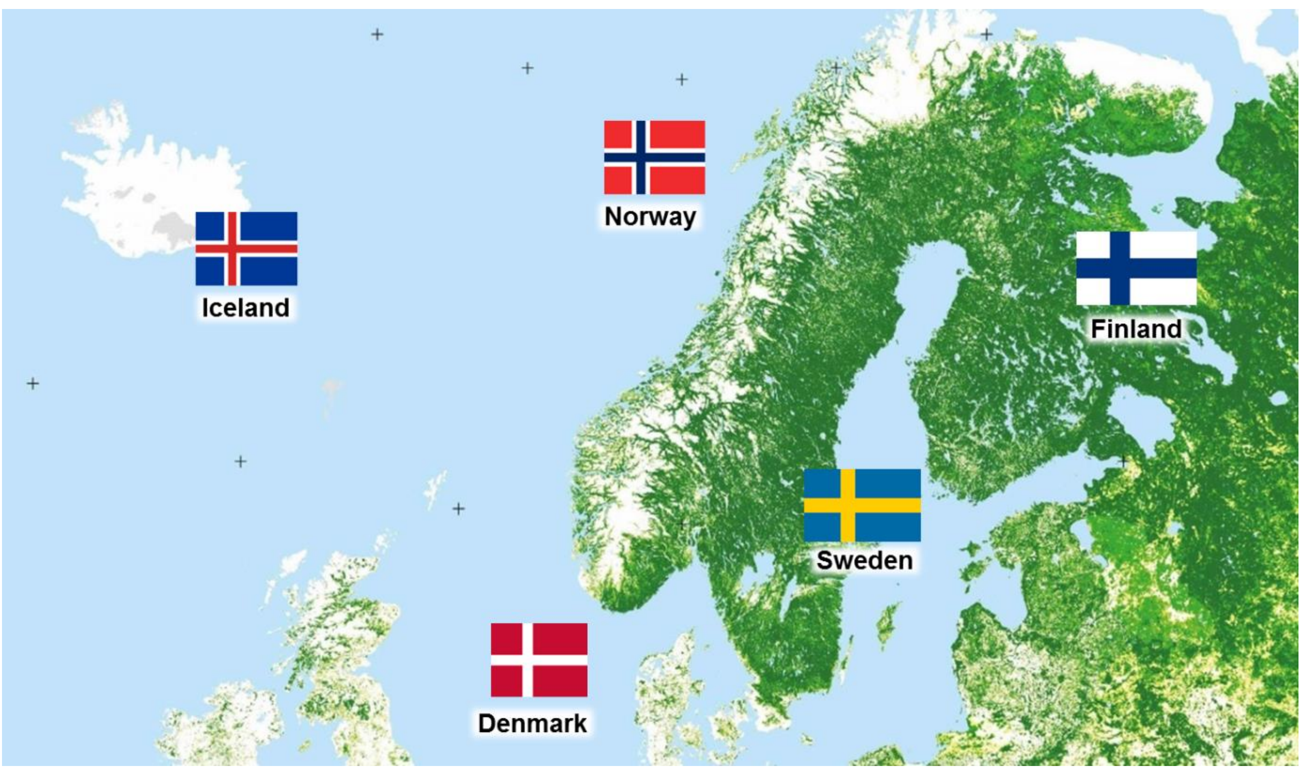


Figure 1. Countries included in Scandinavia regarding this keynote.

# 2 Iceland

## 2.1 Forest facts

Since the 1950s, afforestation by planting trees has been a priority in Iceland. Planting done by forestry societies increased greatly during the 1950s, reaching over 1.5 million seedlings per year in the early 1960s. The principal species planted, besides birch, were exotic conifers like Norway spruce, Sitka spruce, Scots pine, Lodgepole pine and Siberian larch.

Figure 2. Wood from the thinning of a 50-year-old Sitka spruce forest planted in the early 1960s now destined for chipping.

Planting declined in the middle of the 1960s and remained at 0.5-1 million seedlings annual to the late 1980s. After that, afforestation through planting has increased to 4 million seedlings annual throughout most of the 1990s. Today about 6 million seedlings are planted per year (Eysteinsson 2013).

## 2.2 Reforestation challenges

Iceland once had a forest cover of up to 60%, mostly with birch forests whereas today, forest coverage is around 2% (Fig. 3). Due to extensive logging, land degradation and soil erosion, Iceland faces major reforestation challenge (Arnalds and Barkarson 2003; Eysteinsson 2013). Some of the most common species included in this challenge are birch, Siberian larch, Sitka spruce and Lodgepole pine.

The challenge also includes conflicts with livestock farmers (Arnalds and Barkarson 2003; Halldorsson et al. 2008). For centuries commons were used for horse and sheep grazing. However, more and more of the grazing lands have been fenced up (Fig. 4) allowing the regeneration of birch and other species.


Figure 3. Reforestation in Iceland, a real challenge.

Figure 4. Grazing by sheep controlled by fencing.

Regarding land degradation and eroded soils, forest regeneration often starts by planting Siberian larch in order to establish a humus layer produced by the litter from the needles falling of each year followed by, for example, the planting of Sitka spruce. Some forest nurseries have also been established in recent years adding to the picture of a rising hope for increased future efforts regarding forest regeneration in Iceland.

## 3 Norway

### 3.1 Forest facts

Almost 40% of the surface area in Norway is covered by forests (Fig. 5). The total forested area amounts to 12 million hectares, including more than 7 million hectares of productive forests. 15% of productive forests have been estimated as non-economic operational areas due to difficult terrain (mostly steep) and long distance transport. This means that economical forestry can only be operated in about 50% of the total forested area. Regarding tree species in Norway, the most important are Norway spruce (47%) and Scots pine (33%). Birch represents an important species (18%) (Nordic Forest Owners´ Association www.nordicforestry.org).

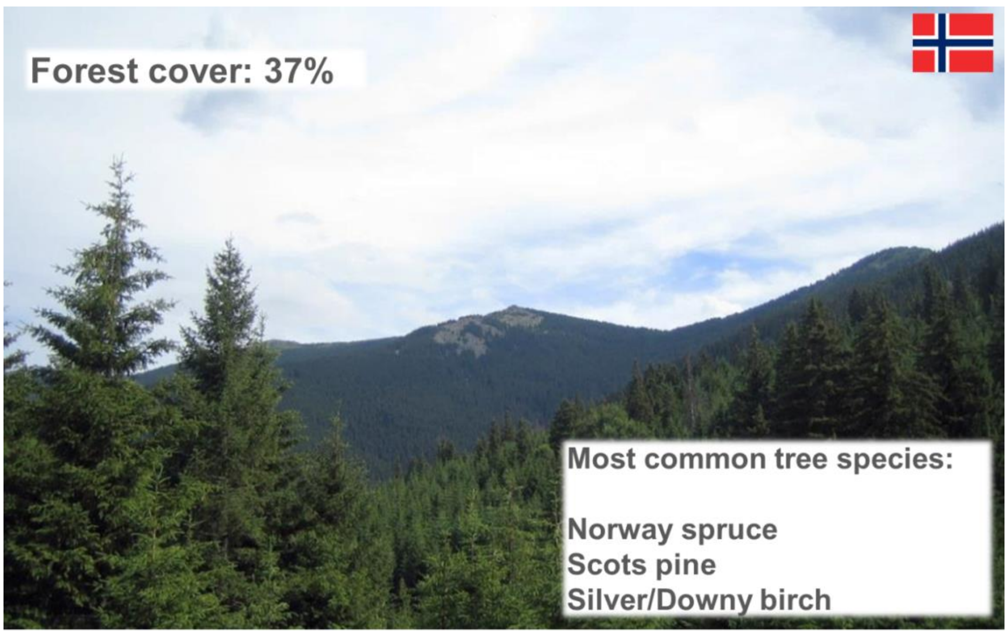


Figure 5. Typical Norwegian forest landscape in mountainous terrains.

Standing volume of the forest is about 750 million m³, compared with 300 million m³ when the first national forest survey was carried out in 1919. The tremendous increase is a result of a forest policy with the main objective of restoring forest resources. The annual increment of Norwegian forests is approximately 25 million m³. The total annual harvest is less than 50% of this growth, about 10 million m³, which means that the amount of trees in Norway forests increases significantly every year.

In Norway, 84% of the forest is private property. The state and municipalities own 12% and forest companies only own 4%. There are a total of 120,000 forest holdings in Norway, with more than 2.5 hectares of forestland. The average size of a forest holding is about 50 hectares. Small forest properties, steep terrain, varying terrain conditions, and the varying production possibilities have created great variations within the forest landscape.

The forest along the coast is often very valuable, but is usually on a steep terrain. Therefore, logging operations are generally done using cable cranes (Samset 1985; Torgersen and Lisland 2002) and the transportation of logs is done by helicopter (Fig. 6).

Figure 6. Logging by cable crane and transportation of logs from the site supported by helicopter.

## 3.2 Reforestation challenges

A major reforestation challenge in Norway has for decades been the risk of seedling damages from pine weevils. Unprotected seedlings can have a survival rate of less than 25% after being planted. The pine weevils feed on the bark of planted young seedlings at regeneration sites. If the seedling is girdled, it will not survive (Hanssen 2010 and 2011). To reduce the damages from pine weevils, chemical protection has been used in Norway for many years (Kohmann 1999).

Figure 7. Planting operations with containerized seedlings and planting tubes. Bottom right: a pine weevil feeding on the bark of a young seedling.

In Sweden, and soon in Norway, major restrictions on the use of pesticides for protection from pine weevil attacks have recently been introduced. Therefore, future protection of seedlings against pine weevils has to be based on silvicultural or non-chemical methods.

Since seedling damage caused by pine weevils (Fig. 7) is one of the major reforestation challenges in Sweden as well, impacts and possible methods to reduce pine weevil damage will be discussed under the heading "Sweden".

## 4 Sweden

### 4.1 Forest facts

Sweden is the third largest country by area in Europe and has the biggest afforested area, where productive forests cover about 27 million hectares. About 70% of the country is covered in forests (Fig. 8). Swedish forests are primarily boreal. The rotation period of the forest varies from 65-110 years, depending on the species (spruce shorter than pine) and geographical location. Due to effective and far-sighted forest management, the total standing volume in Sweden has increased by more than 60% in the last hundred years. Now it amounts to 3,000 million m³ (Nordic Forest Owners´ Association www.nordicforestry.org).

Norway spruce makes up 41% of the total forest mass, Scots pine - 40%, birch - 18%. The remaining 6% consists of other deciduous trees. Growth has been more rapid in southern Sweden compared to the north, due to climatic and soil conditions. In recent years, timber quantities have been between 85-90 million m³, whereas annual growth amounts to about 120 million m³. In order to increase logging amounts, improved forestry methods are required. Current studies indicate that wood production can be increased by up to 20% by 2050 by means of improved forest management.

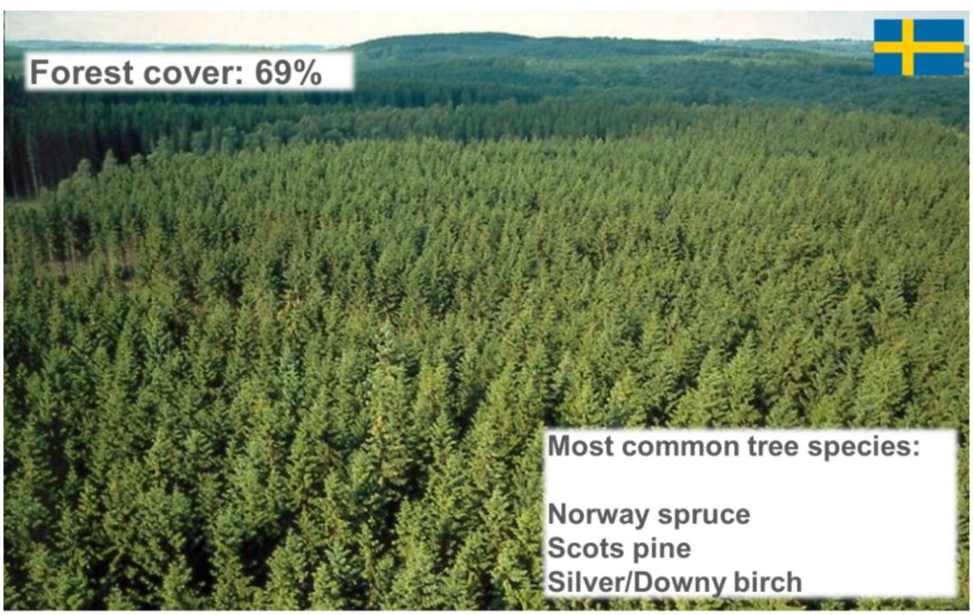


Figure 8. Sweden has an extensive forest cover of mostly Norway spruce and Scots pine.

In Sweden, private individuals own 50% of the forests. The average size of a privately owned forest is about 50 hectares. Large forest companies own 25% and another 25% is owned by the state and other public organizations. In total there are 355,000 forest owners in Sweden. The ownership conditions of a forest in Sweden vary between regions. In the southern parts of the country, private persons mainly own forests whereas in northern Sweden, companies own more significant amounts.

In many parts of Sweden, especially in the south, we have forest stands with a good volume growth. This implies intensive forest harvesting operations for delivery to our pulp/saw mills (Fig. 9). In Sweden, about 80 million $m^3$ is harvested each year and used as pulp for paper production or as timber for wood constructions.

Figure 9. Forest harvesting with a modern, single grip, harvester with a capacity of up to 50 $m^3$ per machine hour.

## 4.2 Reforestation challenges

To manage reforestation challenges after extensive harvesting operations, Swedish forest nurseries produce about 400 million seedlings (Fig. 10) each year for planting operations (Lindström and Mattsson 1994). The production is almost only based on containerized seedlings, making us one of the largest producers in the world of this plant type.

Before discussing the mutual reforestation challenge in Norway and Sweden regarding how to reduce seedling damage from pine weevil, the additional reforestation challenge for Sweden in producing millions of seedlings each year for planting operations will be discussed.

Today seedlings are produced in large conventional plastic greenhouses limiting the production time to the short vegetation period in Sweden. Also, environmental and cost issues are involved in the discussion of how future production technology should be outlined.

As almost all greenhouses are heated by oil, the consumption for a greenhouse is very high. This is based on the fact that production normally has to start in March for requested volumes. At this time of the year, outside temperatures can be -20°C, whereas the temperature inside the greenhouse has to be +20°C in order to reach high seed germination.

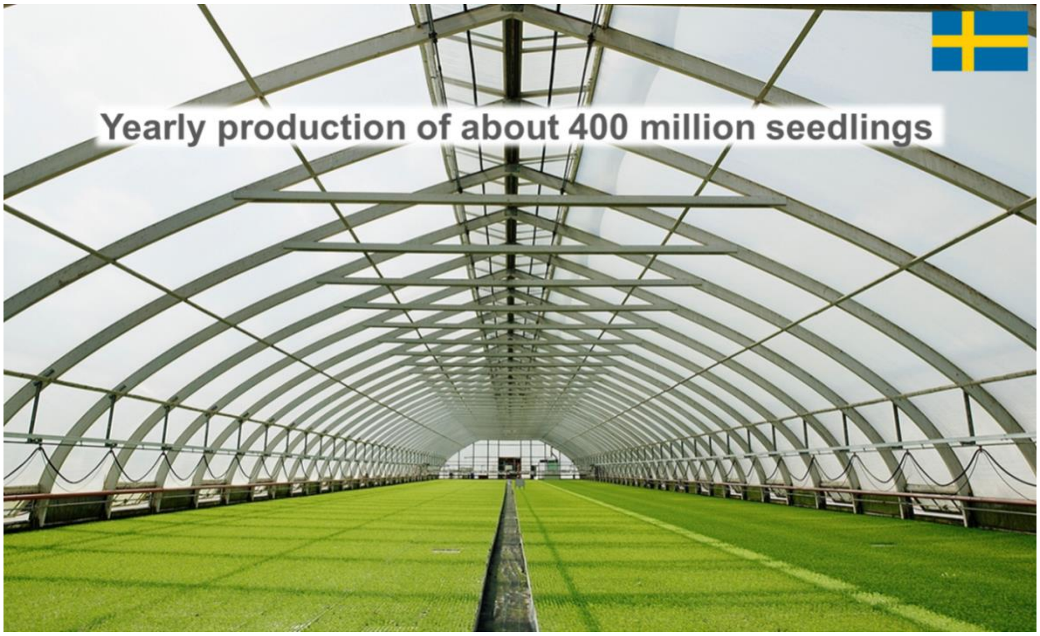


Figure 10. A conventional greenhouse at a Swedish forest nursery. Typical size: 20 meter wide and 100 meter long.

Therefore, Dalarna University in Sweden is involved in a EU-project (acronym Zephyr) regarding new innovative technology for production of forest seedlings without using conventional greenhouses (Hernandez Velasco and Mattsson 2014). This project can really be seen as a major reforestation challenge.

The technology (Fig. 11) is based on a short pre-cultivation period in a growth chamber at high seedling density. For our major species, Scots pine and Norway spruce, 3,500 seedlings $m^{-2}$ followed by automatic transplanting to any optional container system, and after transplanting final growth outdoors without using conventional greenhouses.

In addition the concept includes, among other things, LED lights providing maintenance free, energy efficient, and low thermal emittance, as an alternative to traditional light sources (Landis et al. 2013). The life span of a LED light is almost 10 times longer compared to conventional lighting. The new technology also includes a photovoltaic system and wireless sensors in order to control the climate and soil conditions. With this system it would be possible for Sweden to produce forest seedlings on a year-around basis without using conventional greenhouses.

In co-operation between Dalarna University and one of the major forest companies in Sweden, the technology with pre-cultivation followed by transplanting to outdoor cultivation has been introduced commercially at one forest nursery. As can be seen in Figure 12, the total annual production of 14 million seedlings can be pre-cultivated on an area of about 100 m² without using conventional greenhouses.

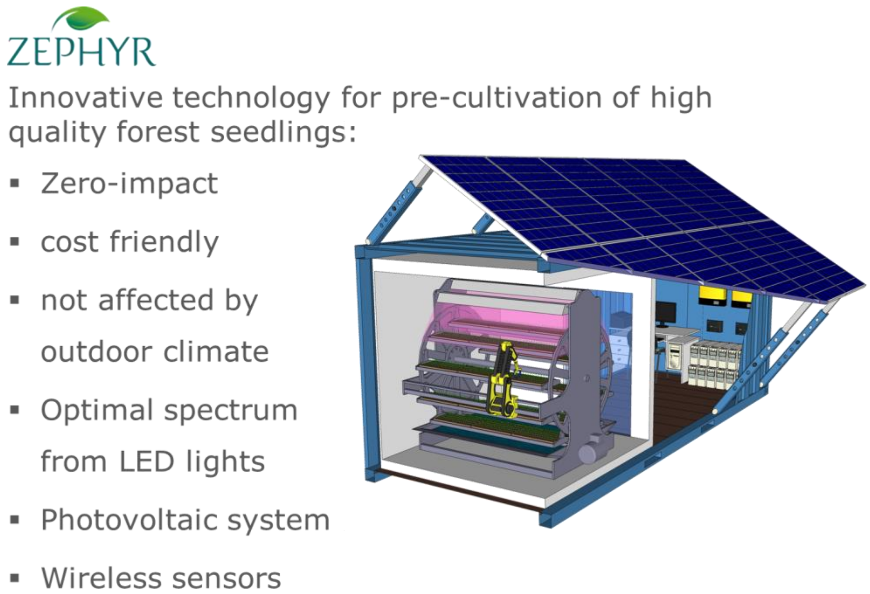


Figure 11. Outline of the Zephyr pre-cultivation incubator.


Figure 12. Circulating multiple floor pre-cultivation chamber for large-scale production of Norway spruce and Scots pine seedlings.

Now back to the other reforestation challenge that we share with Norway -how to reduce the effect of seedling damage caused by pine weevil (Eidmann and Lindelöw 1997). Pine weevils are attracted to fresh clear-cuts by the smell of monoterpenes and ethanol released upon cutting. After feeding on fresh slash, the weevils mate and the female lays her eggs in the roots of the stumps. The new generation hatches the second autumn, and start feeding on the fresh bark of the newly planted seedlings (Fig. 13).

There is a potential risk of pine weevil attacks in many countries in Europe. The magnitude of the problem is connected to the fact whether or not chemical treatment is allowed in a specific country.

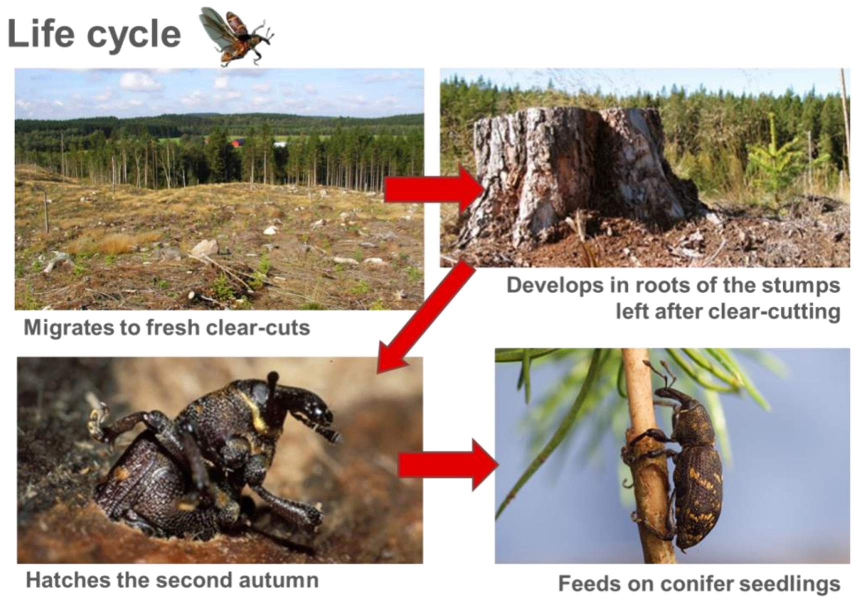


Figure 13. Pine weevil life cycle.

Figure 14 show a risk ranking made in a unique European project (Långström and Day 2004). As can be seen, there was no data available from most of the Balkan countries at the time, so of course there could be a potential risk of attack in this part of Europe as well.

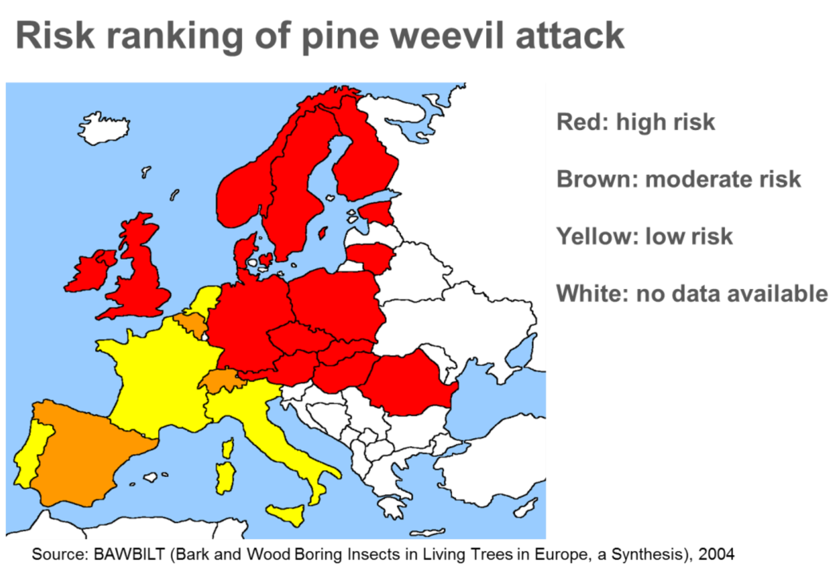


Figure 14. Risk ranking of pine weevil attacks in Europe.

In Sweden, the pine weevil damage is estimated to a cost of about 30 million USD per year. In recent years a lot of efforts and money have been allocated to the problem and methods to reduce pine weevil damage without using chemicals have been developed or are developing (Nilsson et al. 2010; Nordlander et al. 2011).

These includes, as shown in Figure 15, both silvicultural methods (von Sydow 1997) and mechanical protection of single seedlings.

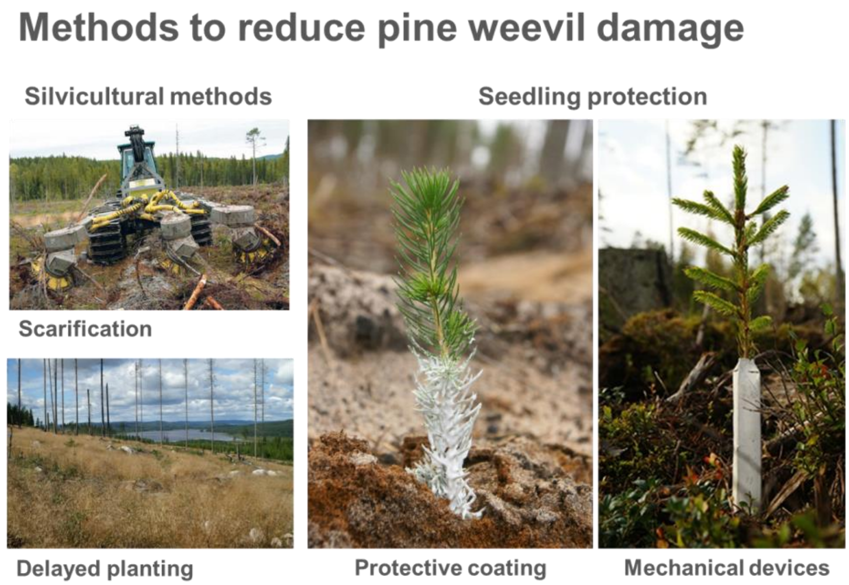


Figure 15. Silvicultural or mechanical (coating or tubes) methods for preventing damage from pine weevil attacks.

In the first category, scarification (Petersson and Örlander 2003) and delayed planting have been used. Scarification has shown to be quite effective since pine weevils do not find areas with pure mineral soil attractive, therefore, they don't invade seedlings planted on that specific type of soil, compared to a seedling planted in an intact humus layer that has more vegetation and humid conditions.

Delayed planting can reduce the attacks since the amount of weevils will be reduced each year due to lack of suitable feeding materials. The problem is the fast introduction of weeds, making the establishment of young seedlings difficult due to increasing competition for light, water and nutrients.

The introduction of direct protection of each seedling by coating or mechanical devices has shown to be a very promising method. These methods have now been introduced in a large-scale in Swedish forest nurseries.

Looking at how the proportion of chemical or mechanical protection of seedlings (Fig. 16) used in forest regeneration in Forest Stewardship Council (FSC) holders in Sweden (all major forest companies) has changed during the past four years, it is clear that chemical treatments have decreased (Giurca and von Stedingk 2014).

Still a large portion of all planted seedlings were left untreated during 2014. This is due to the fact that in northern Sweden the pine weevil population is, due to climatic conditions, rather small compared to southern Sweden that has much more favorable conditions for an intensive forest yield (compared to the harsh conditions in northern Sweden).

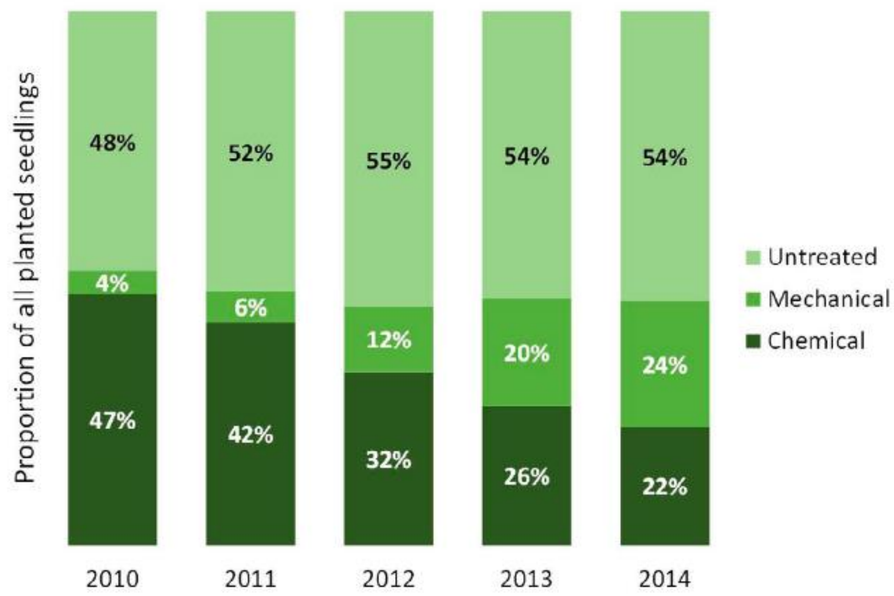


Figure 16. The proportion of all types of seedlings (untreated and mechanically/chemically treated) used in regeneration by FSC holders during the past four years.

Data also shows that pesticide applications have been decreasing from the total (chemical and mechanical treatment) proportion of treated seedlings (Fig. 17). According to predictions, all FSC holders are expected to completely cease pesticide application by 2019 at the latest (Giurca and von Stedingk 2014).

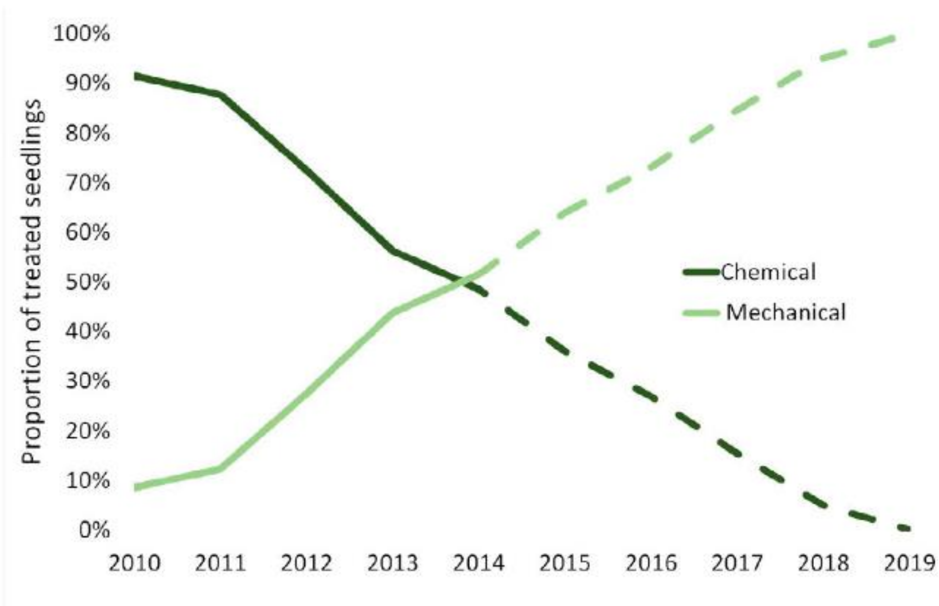


Figure 17. Proportions of chemical and mechanical treatment for all FSC holders. Dashed lines show predictions. Note that untreated seedlings are not included in the calculation.

# 5 Finland

## 5.1 Forest facts

Finland is Europe´s most heavily forested country with 75% of the land area (Fig. 18), representing 23 million hectares, under forest cover. There is an additional 3 million hectares of sparsely wooded forest areas, treeless open mires, and rocky forestland. Taking all of this into consideration, you will see that forestry land accounts for 86% of the land area. Nearly all of Finland belongs to the boreal coniferous forest zone, which is characterized by a short growing season and limited number of species. Due to the Gulf Stream, however, conditions in Finland are more favorable than in other places on the same latitude.

There are four coniferous species native to Finland and over twenty species of deciduous trees. Just like in Norway and Sweden the most common species, which also are economically most significant, are Scots pine, Norway spruce, and silver and downy birch. Regarding these species forest cover in Finland includes 50% Scots pine and 30% Norway spruce leaving 20% for the broadleaved species (mostly birch). In contrast to Norway and Sweden, the amount of birch planting and birch stands are quite significant in Finland. Beside forestry, Finland is also known as the land of the thousand lakes as illustrated in Figure 18.

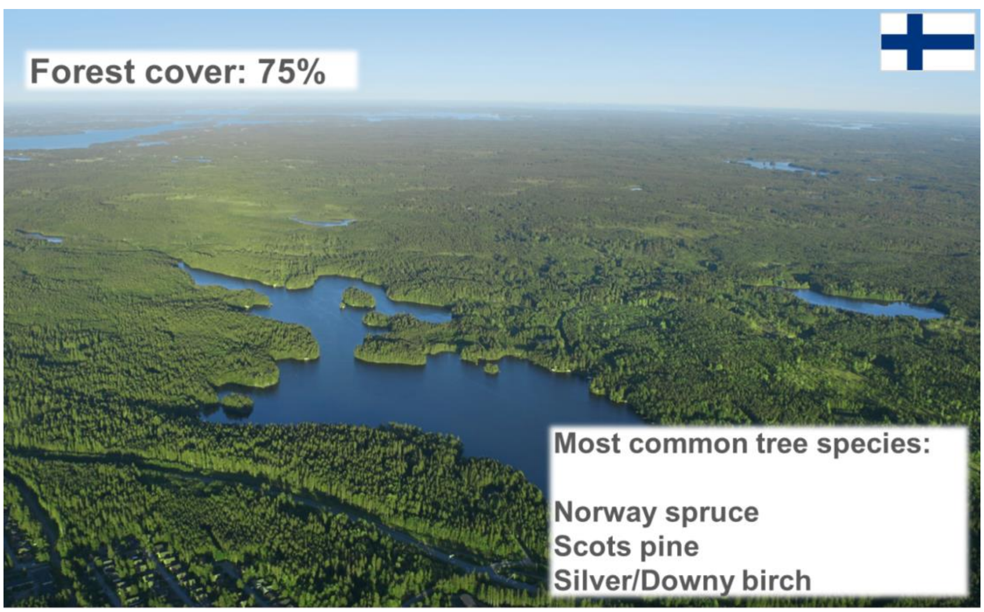


Figure 18. Finland: a country of forests and lakes.

The total volume of growing stock in Finnish forests amounts to about 2,200 million m³. Since the late 1960s, the volume and increment of the growing stock have continuously risen and is now almost 50% higher than four decades ago. The annual increment of Finnish forests is about 100 million m³ where the maximum annual harvest is evaluated to be about 70 million m³ (Nordic Forest Owners´ Association www.nordicforestry.org).

Private individuals own 60% of all forestland. The number of private forest holdings of at least one hectare is about 440,000 and the number of individual private forest owners is estimated to be around 920,000. This means that almost every fifth Finn is a forest owner. The state and municipalities own 30%, while forest companies own the remaining 10%.

Finland has a long tradition in producing and planting birch seedlings. A forest stand is often a mix of birch and spruce with birch as a nurse stand and Norway spruce established as an understory (Valkonen and Valsta 2001). In Finland birch is known as the mother of the spruce since the conditions, such as light and others, under a birch stand are very good for spruce development (Fig. 19).

Figure 19. A typical mixed birch and spruce forest stand in Finland.

## 5.2 Reforestation challenges

A major reforestation challenge in Finland is linked to the forest structure. The structure of Finnish forestry includes many private forest owners in combination with small regeneration sites (Leppänen and Nuoro 2006) where one estate is in average 30 hectares. Private forestry plays a key role in Finland because 80% of Finnish wood used by the forest industry comes from privately owned forests. In the southern part of Finland with the most productive forest, private forest ownership is as high as 80%.

This implies a situation where logistics and methods for lifting in combination with field storage at the site provide a major reforestation challenge in order to preserve seedling quality until the planting date (Lilja et al. 2010; Nilsson et al. 2010). Small quantities of seedlings have to be delivered to each small regeneration site in a relatively short planting season due to climate conditions. This implies problems to be able to take care of the seedlings while maintaining their quality. Thus forest owners have to water the plants at the field storage with portable water systems (Fig. 20).

Figure 20. Watering of seedlings at field storage by a regeneration site.

Due to this situation, a major reforestation challenge for Finnish forestry is to develop new logistic systems and technology, including new seedling cultivation programs, to match the access of fresh planting stock to a lot of small regeneration sites in combination with different planting dates.

# 6 Denmark

## 6.1 Forest facts

Danish forests cover about 550,000 hectares which is about 13% of the total land area (Fig. 21). Denmark is the northernmost of the central European temperate forest zone, just south of the boreal coniferous forest zone. Therefore the climate conditions allow more variations in forest species compared to other Scandinavian countries. The most common tree species are Norway spruce (19%), beech (13%), Scots pine (12%) and oak (9%). Species used as Christmas trees and greenery production, mainly Nordmann and Noble firs, adds up to 6% (Nordic Forest Owners´ Association www.nordicforestry.org).

The total volume of the growing stock in Danish forests amounts to about 110 million $m^3$. The growing stock and forest area have been constantly increasing from a level of about 3% forest cover in the early 1800s. Today the annual increment is calculated to be 5.5 million $m^3$, whereas annual logging amounts to 2.2 million $m^3$.

In Denmark private persons own 65% of all forestland. Private foundations own another 4%. The number of private forest holdings amounts to 25,000. The Danish state owns 23% of the forestland. Mostly municipalities publicly own 8%.

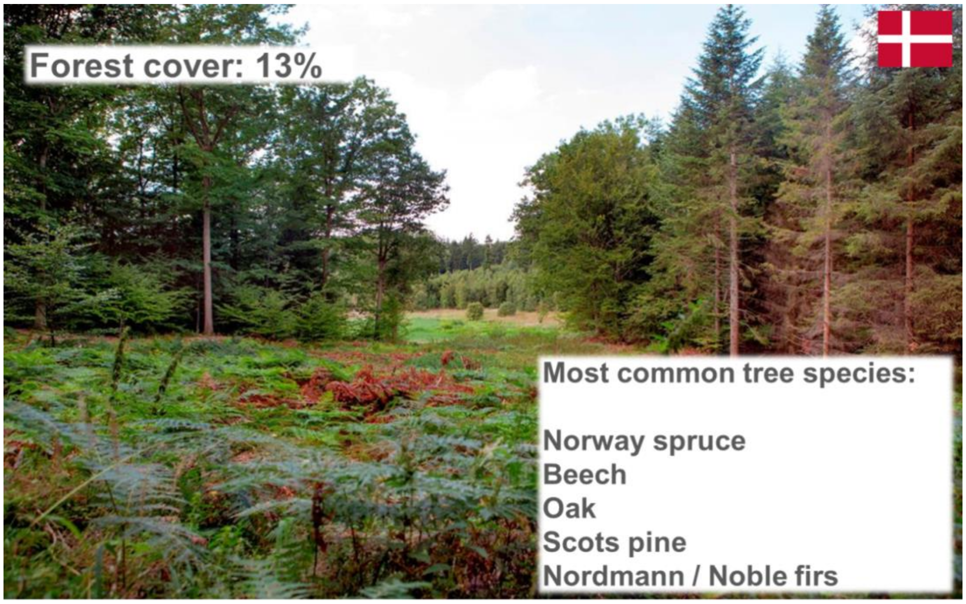


Figure 21. The forest cover could be increased in Denmark due to favorable climatic conditions.

## 6.2 Reforestation challenges

Although the conditions allow more variations (Fig. 22), spruce monocultures have been established in many places mainly due to economic reasons. A major future reforestation challenge for Denmark is the possibility to establish plantations based on a wide range of relevant species (Jacobs et al. 2015).

Figure 22. Climatic and soil conditions allow a wide range of species to be cultivated in Denmark.

For this option, new methods and technology have to be developed in reforestation activities that support this possibility. These methods and technology should make it possible not to be limited to certain species due to problems and restrictions during field establishment (Stanturf et al. 2014).

In a forest with a wide range of species the risk of specific species being attacked by, for example, a fungi disease will be limited. Also a wide range of species will in general make the forest more stable, healthy and productive and in that way also more adapted to future climate change (Bolte et al. 2009).

With this I conclude my presentation of forestry in Scandinavia and the reforestation challenges lying ahead.

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