AFFORNORD

Effects of afforestation on ecosystems, landscape
and rural development

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*Effects of afforestation on ecosystems,
landscape and rural development*

Edited by:

Gudmundur Halldorsson,
Edda Sigurdis Oddsdottir and
Bjarni Didrik Sigurdsson

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Preface

Gudmundur Halldorsson and
Edda Sigurdis Oddsdottir

The present book is the result of the Nordic project AFFORNORD – the Effects of Afforestation on Ecosystems, Landscape and Rural Development. This project was launched in 2004 as a theme project of the Nordic Council of Ministers, appointed by the Icelandic Ministry of Agriculture. Professors, administrators, scientists, M.Sc. and Ph.D. students from 11 different Nordic universities, institutes and organizations contributed to the project.

The goal of the AFFORNORD project was to analyse the effects of afforestation on ecosystems, landscape and rural development, primarily within Denmark, South Sweden, West Norway, Iceland and the Faroe Islands. The examples and data presented here are primarily from this region where deforestation, and subsequently afforestation, has been most intense in the past. The large scale afforestation process started in the 19th century in Denmark, in the 1930s in West Norway and in the 1990s in Iceland. This time span affords opportunities to use experience from regions which have gone through the afforestation process for the benefit of others that are in the primary phases of afforestation.

The aims of afforestation have been to positively influence rural development, create or improve natural resources, restore lost ecosystems and improve living conditions, as well as to mitigate the constantly increasing concentration of atmospheric carbon dioxide. However, there has been a significant concern that afforestation might also have negative effects, especially on biodiversity and the landscape. This dialogue is also known from the British Isles, where use of exotic tree species has been criticised, e.g. because of an alleged negative effect on birdlife and the landscape. This discussion is becoming more intensive in countries where afforestation has recently started, as in Iceland. The positive effects of afforestation on rural development have also been questioned.

There are many studies known from different fields where the effect of afforestation has been examined, including Nordic studies. In the AFFORNORD project we link together different studies to create a holistic view of the effects of afforestation. This is necessary as optimising one parameter, for example production, might have negative effects on others, such as biodiversity and the landscape. Although there are many studies on forest ecosystems in the Nordic countries, there are certain gaps in our knowledge that need further research. The effect of afforestation on soil fauna is a research field that has not received much attention, even though it may provide key information on the changes in biodiversity. Furthermore, soil fauna play an important role in the decomposition process and in soil fertility. It was therefore decided to focus on the diversity of one soil fauna group, Collembola.

The AFFORNORD project has been carried out in three major steps: a) linkage of different Nordic research projects, b) common field studies (Collembola), and c) consolidation of knowledge, through joint courses, workshops and a conference. The project held an international conference on the effects of afforestation on ecosystems, landscape and rural development in Reykholt, Iceland, in 2005. The conference was attended by almost 100 scientists, administrators and forest planners. There were three parallel sessions in the fields of ecosystems, landscape and rural development where the latest results were presented. The proceedings of the conference contained 43 scientific papers and have already been published as part of the TemaNord series.

In the present book we have compiled and synthesized information from the proceedings together with information from projects and field studies involved in the AFFORNORD project. The aim of this book is to give a holistic view of the effects of afforestation on ecosystems, landscape and rural development and propose guidelines for improving planning of afforestation.

Many individuals and organizations have supported the AFFORNORD project. For this we would like to express our gratitude. We thank the Icelandic Agricultural Ministry for proposing AFFORNORD as the Icelandic theme project in 2004. The project was funded by the Nordic Council of Ministers. Dr Magnus Gröntoft, secretary of the Nordic Environment Strategy for Agriculture and Forestry, has been our contact person within the Council and we would like to thank him for his invaluable help. Last but not least, we would like to thank all those that contributed to this book, especially members of the AFFORNORD project group and those who participated in the conference or other AFFORNORD activities.

Summary

AFFORNORD is a collaborative research project under the Nordic Council of Ministers. The aim of the project is to give a general overview over the effects of afforestation on ecosystems, landscape and rural development. In this book we discuss the effects of afforestation in relation to wood production, biodiversity, landscape, public health, rural development and carbon sequestration.

The most important conclusions from the project are as follows:

Wood production:

- Wood production is primarily dependent on tree species in relation to climatic and soil conditions. Selection of tree species is therefore of major importance.
- Timber and fuelwood is the primary source of direct revenue for many forest owners and their primary motivation for multipurpose forest management.
- International competition will presumably maintain low prices on traditional wood products for the foreseeable future. However, increased use of wood products for heating and bioenergy, to counterwork the greenhouse effect, can possibly increase the prices in the future.
- There is a direct relationship between the development of regional business activities and the private- and socioeconomic potential of afforestation.

Biodiversity:

- Afforestation changes species composition for all functional groups, even if the total species richness may not be affected.
- Afforestation increases significantly species richness of fungi and soil invertebrates.
- Afforestation in areas or habitats which are important for specific species is of significant concern.
- The effects of afforestation on biodiversity can vary from one region to another and any general rule on these effects must therefore be applied with certain precautions.

Landscape and public health:

- Afforestation may cause loss of view and can thereby change the impression of the form and construction of the landscape.
- New forests must be designed in such a way that they conform with the other elements and the character of the landscape. Sharp, straight borders should be avoided. It is also important to maintain open areas within the forest with a view over the landscape.
- Afforestation can cause irreversible changes to cultural heritage and can damage archaeological sites. This must be avoided by careful planning of new forests.
- Afforestation can be effectively used to stop erosion and can thereby play an important role in protecting specific landscapes and physical installations in the landscape.
- There is a positive relationship between human experiences of nature and health. People seem to react differently, but most often positively, to the natural environment compared to urban sites. A forest is an ideal alternative for offering varied nature experiences and for reloading ones mental and physical strength.

Rural development:

- Afforestation can have a positive effect on economic activity and employment in rural areas, but does not always manage to halt negative population development.
- It can take a very long time before the effects of afforestation on rural development are fully realized.

- Increasing the number of small-scale private owners contributes to new forest functions that aim for multifunctional utilization rather than wood production.
- The effects of afforestation differ between different Nordic societies and regions.
- Afforestation programs can compete with other land use.

Carbon sequestration:

- Afforestation reduces atmospheric CO₂ by net carbon storage in biomass and soils.
- Selection of tree species and forest management practices can increase the net amount of carbon taken up and stored.
- It is not necessarily the fastest growing tree species that have the highest carbon sequestration potential at a given site.

There is no doubt that afforestation affects ecosystems, landscapes and rural development in several ways, positive as well as negative. No land-use, whether it is afforestation or other uses, meets all environmental goals simultaneously. Some negative impacts are inevitable, even if the most conscientious management is employed. Generally, a trade-off must be made between the desire for a more-or-less pristine environment and the need for a working and operational landscape for the benefit of society at large.

Opposite page: Birch seedling in Iceland. Photo: Edda Sigurdis Oddsdottir.

History of afforestation in the Nordic countries

Olafur Eggertsson, Per Holm Nygaard
and Jens Peter Skovsgaard

Vegetation history

The last late glacial from 22,000 up until just before 13,000 years ago was very cold and dry throughout Europe. Large ice sheets were present over much of northern Europe, and ice caps covered the Alps and the Pyrenees. Forest and woodland were almost non-existent, except for isolated areas of woodland vegetation and close to the mountain ranges of southern Europe. Instead, a sparse grassland or semi-desert covered most of southern Europe, at the same time as a mixture of the dry, open steppe tundra and polar desert covered the parts of northern Europe not occupied by ice sheets (Figure 1). Ice-wedge geomorphological features suggest that permafrost extended across most of Europe, down to about the latitude of central France. At this time drifting sand and wind erosion were common in north and central Europe.

At the glacial maximum in Fennoscandia, only the south-western part of Jutland was ice free and a large part of what is today the North Sea was dry land connecting Jutland with Britain. The ice sheets also covered the whole of Iceland and the Faroe Islands (Figure 1).

Conditions then quickly became warmer and moister, and similar to the present, although with a strong cold dry event around 11,000 years ago (The Younger Dryas event). Around 8,000–5,000 years ago climatic conditions seem to have been slightly warmer than at present across central and northern Europe.

Figure 1. Last glacial maximum in Northern Europe, ca 20 thousand years ago. Glaciers covered Fennoscandia, Faroe Islands and Iceland, whereas, South-West Jutland and most of southern and central Europe was ice free and covered by steppe-tundra vegetation.

Figure 2. A pollen diagram from the inner Oslo Fjord, Norway, showing the immigration of different tree species into the region after the last glaciation. Based on Ulf Hafsten 1957.

When the ice sheet started to melt away tree species began to colonise the ice-free regions. Some fragments of vegetation may have survived during some periods of the glaciations in Fennoscandia and Iceland (on nunataks), but the most common opinion is that most species that are present in this region immigrated during and after the deglaciation.

During the first colonisation phase in Fennoscandia birch, juniper, aspen and Scots pine reached the area. As climate improved and became warmer, similar to the present day climate, species like hazel, oak, elm and lime immigrated and established through the boreal, Atlantic and subboreal period. Norway spruce and beech immigrated later, as the climate shifted towards cooler and moister conditions some 4000 years ago (Figure 2). Most of these tree species never reached Iceland or the Faroes, due to geographical isolation. Pollen analyses show that birch species colonised both countries soon after the glaciers started to retreat. In the Faroes the distribution of birch was most wide-spread 9500–9000 years ago, but after that birch species seem to have retreated and stayed at a relatively low level until the settlement of the islands. Soon after the settlement downy birch disappeared completely from the Faroes. In Iceland the distribution of birch was greatest 9000–7000 years ago. The birch forests retreated again for a period of 2000 years due to climatic change. The climatic conditions improved ca. 5000 years ago and the distribution of birch increased again and it has been

Figure 3. A characteristic soil profile from Icelandic mire with a birch and willow pollen diagram. During the boreal (9-7000 years ago) and the subboreal (5-2500 years ago) the mires became dryer, represented as log horizons in the mires and increase in birch pollen. Illustration by Thorbergur H. Jonsson, pollen diagram based on Thorleifur Einarsson 1991.

estimated that at the time of the settlement in the late 9th century 20–30% of Iceland was covered by birch forests (Figure 3).

During the last 5000 years the forests of Fennoscandia have been influenced by human impact, including slash and burn practices, grazing, and production of timber, firewood, charcoal, iron, tar, potash, and fuel. In Iceland and the Faroes this occurred much later, i.e. between AD 500 and 900. Human impact has led to large-scale forest clearance, especially in the southern (Denmark, South Sweden) and western (West Norway, the Faroes, Iceland) part of the Nordic region. In the Faroes forests had completely disappeared around AD 1000, forests covered only 2–3% of Denmark in the beginning of the 19th century, and the forest coverage in Iceland was below 1% in the beginning of the 20th century.

Table 1. The forest cover in different countries in the Nordic region (in thousands of hectares).

	Faroes	Iceland	Denmark	Norway	Sweden	Finland
Forest	0	43	500	9387	27528	22500
Other wooded land	0,1	106	136	2613	3257	802
% forest and other wooded land of total area of country	0,1	1,5	14,8	37,1	68,4	68,9
Total area of country	140	10300	4309	32376	44996	33814

Present forest cover in the Nordic region ranges from 0.1%, in the the Faroes, up to 69% of the land area in Finland (Table 1).

Figure 4. The estimated woodland cover in Iceland before it was settled in the late 9th century (left, approximately 30% woodland) and today (right, approximately 2% woodland).

Historical background of afforestation

As stated earlier, afforestation in the Nordic region has been most intensive in the southern (Denmark and South Sweden) and western (West Norway, the Faroes and Iceland) part of the region. Throughout this region steps have been taken to protect existing forests and establish new ones.

The Danish Forest Act of 1805 introduced the concept of forest reserves, which was applied to the majority of forested land at the time. Forest reserves, in principle, could not be converted to other land uses and management had to comply with good forestry practices, primarily aimed at wood production.

By the late 1860s an emerging national movement towards the utilisation of the vast areas of barren heathland in Jutland provided a foundation for afforestation activities that lasted essentially unchanged for a century. Initiatives were triggered by a number of factors that do not relate directly to forestry. The loss of one third of the Danish land area in 1864 following a war with The German Federation (Prussia and Austria), enhanced patriotism, industrial development, and substantial public grants were some of the driving forces.

The most conspicuous factor appears to be the loss of land due to war. *Land lost outwardly should be regained within the country* became a successful slogan for heathland afforestation. At the same time there was a strong belief that afforestation would be a major factor in promoting economic development for the benefit of land owners as well as entire local communities. This was probably the main argument for almost a whole century, but recent research disproved the theory.

Heathland plantations were established by different groups of owners: private land owners, co-operatives, newly-rich people in major cities, and the national forest service. While patriotism, expected future income, and regaining past status, lost land and timber resources undoubtedly played a significant role, many private land owners were probably equally persuaded by public grants for afforestation. Next, influential city people who had recently become wealthy through the emerging industry saw an opportunity to establish a contemporary parallel to inherited nobility. Their remote heathland estates also provided secluded recreational opportunities.

During the 1920s renewed interest in continuous cover forestry and the advent of nature conservation led to a halt in afforestation. Subsequently, the economic recession in the 1930s re-started activities to mitigate massive unemployment. Heathland afforestation was promoted until the 1960s, but discontinued due to high employment rates and changes in agricultural policies.

In 1896, The Danish Forestry Society suggested the establishment of an official forestry extension service for owners of small forests only, and since 1904 the government has encouraged small woodlot owners to form associations in order to take advantage of economies of scale. In 1904 the first local Forest Owners Association was founded and government grants were made available to these associations for increasing wood production. The primary aim of the Association at this time was to offer forestry extension services to its members.

Consultants were financed partly by membership fees and partly by The Danish Forestry Society, and smaller forest owners strived to obtain state subsidies for forestry extension services. A committee under The Danish Forestry Society analysed the silvicultural status of the smaller Danish forests, especially in Jutland, and presented their findings and proposals to the Ministry of Agriculture. Consequently, an act which made it possible for the Ministry to grant local Forest Owners Associations the right to operate a forestry extension service for their members was introduced in 1919. In 1939 the seven local Forest Owners Associations had a total of 2,200 members and forest land totalling 13,000 ha.

The outbreak of World War II and compulsory felling started the establishment of new associations. The first local Forestry Extension in the island of Zealand, Denmark, was founded in 1940. The same year the nine existing Associations founded Danish Forestry Extension (DFE) to be able to act jointly and represent the forest owners' interests on a national basis. By 1965 DFE consisted of 16 local units with 5,300 members and a total of 34,700 ha of forest land.

Since 1969 private forests have been open for public access on roads and pathways from 7:00 am to sunset. Moreover, many private forest districts have followed state forest districts in establishing various facilities for public use, such as playgrounds, simple camp sites, information boards, visitor centres, barbecue sites, bird-watching towers, etc. Forest owners, private and public, also make their forest available on a voluntary basis for local schools for education purposes.

A new Forest Act was passed in 1989. The new Act changed Denmark's fundamental management principle from being one of "good forestry" to one of "good and multiple-use forestry". This allowed for the development of a new grant scheme, which was in part to increase the area of broad-leaved stands.

In the 1990s the government was dedicated to doubling the nation's forest area within one rotation (80–100 years), through state afforestation and financial support to private afforestation.

The new Danish Forest Act from 2004 has four primary objectives:

- Conserve and protect the Danish forests.
- Improve the stability of the forest sector, the ownership structure and productivity.
- Contribute to increasing forest cover.
- Strengthen the advisory service and information on good and multiple-use forest management.

As a result, the main objective of the National Forest Programme is full implementation of sustainable forest management, which incorporates economic and ecological as well as social considerations. Among the objectives of this Programme is that forest landscapes should cover 20–25% of Denmark after one tree generation (80–100 years), and the scope and potential for natural habitats and processes should be strengthened.

During the period from 1994 to 2004 an additional 20,000 ha of agricultural land have been afforested in Denmark. Approximately 75% of the afforestation has been done by private landowners, and the rest has been public afforestation projects, mainly by the Danish Forest and Nature Agency (DFNA).

The first steps towards a national afforestation programme in Norway were taken in the late 1930s when the Forest Director (Skogdirektøren 1937) and a committee of the Norwegian Forest Society (Utmarkskomiteen 1939) evalu-

ated the critical forest situation and examined the possibilities for increasing forest investment in the coastal regions. However, World War II made any further action difficult. In 1946, the head of the Forest Research Station of West Norway, Anton Smitt, presented to the Parliament a vision of how afforestation would gradually improve people's quality of life and scenarios for a new wood-based industry. The first really large step was taken in 1951 by the White Paper "Innstilling fra Skogkommisjoen" (Skogdirektøren 1951–54), the basic ideas of which were adopted by the Norwegian Parliament in 1953–54. The major conclusions from this work were:

- In the afforestation areas, each municipality was responsible for setting up their own reforestation plans and programmes for tree planting and setting priorities.
- The government was willing to subsidize up to 50% of the cost of establishing new plantations.

Municipality grants implied that up to 75% of the planting costs were covered from governmental sources (after 1964, 85% of the costs were covered by the government).

Figure 5. The Icelandic Forest Research at Mogilsa around 1970 (top) and 2008 (bottom). The research station is a national gift from the Norwegian people. It was officially opened in 1967 by King Harald V of Norway (then prince). Photos: top Unknown, bottom Edda Sigurdis Oddsdottir.

In Iceland, organized forestry is considered to have started in 1899 with the planting of the “Pine Stand” at Thingvellir. Forestry efforts focused on protecting birch forest remnants during the first half of the 20th century, with several forest areas being acquired by the Iceland Forest Service (IFS) (founded in 1908) for that purpose. These, along with more recently acquired afforestation areas and experimental forests, comprise the National Forest system today.

The Icelandic government did not really become heavily involved until the 1950s, when it became much more active in terms of legislation, research and financial support. Since 1955, forest laws have banned clear-cutting of the native birch forests except by permission of the IFS, and land reclamation is intended to lead to establishment of woodlands where possible.

By adding a forest tax to cigarettes during the 1960s and part of the 1970s, the government was able to support the tree-planting activities of both the private forest societies and farmers.

In the 1980s and 1990s government activities expanded rapidly, with erosion control and recreation as the main objectives. President Vigdís Finnbogadóttir made afforestation a priority and a popular concern. In the years of her term, from 1980 to 1996, the Icelandic state budget for forestry increased, mainly because of support provided for farmers’ afforestation programmes. In addition, private investors, local communities, forest societies and other entities were supporting afforestation.

The latest legislation regarding local afforestation programmes states that at least 5% of the lowland (215,000 ha), shall be transformed into woodlands during the next four decades.

The increase in woodlands has not occurred without conflict with live-stock farmers. For centuries, the commons were used for sheep and horse grazing, and the plantations have had to be surrounded with fences to protect them from animals, resulting in many square plantations around Iceland. However, in recent decades the number of grazing animals has declined. More and more of the former pastures have been fenced in, allowing both natural regeneration of birch and plantations of this and other species.

Why afforestation?

The aims of afforestation within the Nordic region are many and depend on various factors. Earlier, and especially in regions with a strong forest

industry, the primary aim was to build up resources for the timber industry and to have a positive influence on rural development. An example of this is the large-scale afforestation in West and North Norway which began in the late 1950s and early 1960s. Within a period of sixty years the plan was to cultivate 325,000 hectares of land in West Norway and 100,000 ha in North Norway, mostly by establishing highly productive spruce plantations.

Simultaneously, by increasing the productivity of spontaneous woods of broadleaves and pine by improved silviculture the allowable annual cut by 2030 is estimated to reach about 3.7 million m³ in West Norway and about 1.0 million m³ in North Norway. The recommendations about tree species and provenances, cultivation methods and management relied on the results from forest research. Projects were designed both at governmental and local levels. The Norwegian Forest Society and the forest county societies have been designated to undertake parts of the programme, i.e. the production of seedlings. Most municipalities had initiated local afforestation programs in the mid-1950s, and up to the 1980s the plans and time schedules were well adhered to. However, after 1980 there has been an overall decline in tree planting in the afforestation areas due to several reasons:

- The most suitable areas for economically attractive forestry were to a great extent already cultivated.
- The economic support from the government became less favourable.
- The awareness of environmental impact increased and local conflicts emerged.
- The economic contribution from forestry to the farmers' income gradually declined due to lower prices for wood and the higher costs of labour.
- The property structure was still dominated by small scale owners for whom income from forestry became more and more marginal.
- The huge colonization of other forest land of broadleaves and Scots pine in the afforestation areas has called for a more focused effort.

In Iceland large scale afforestation began only by the end of the 20th century when regional afforestation programs were started (Figure 6). This involved direct support from the government to farmers for planting new forests. Farmers could thereby acquire some income for planting on their own land. The primary aim of these projects has been to have a positive influence on rural development. Studies in East Iceland, where these plans

Figure 6. Annual planting in Iceland during 1942-2006. Afforestation suffered from extreme spring frost in 1963 which killed a large proportion of planted forest in southern and western Iceland. This had a negative effect on public interest and it took almost 30 years before the number of planted seedlings equalled previous planting.

are most developed, have shown that the projects have served that aim to some extent. Other aims of these projects have been vaguer. Due to slow growth, significant income from timber production can only be expected by the late 21st century and as the country does not have any significant timber industry or tradition for utilising timber products it is difficult to estimate what will be the value of these forests as a resource for any future timber industry. Other benefits from afforestation in Iceland are environmental, such as soil protection and carbon sequestration, and social, such as forests for amenity and recreation.

In general there has been a shift in the focus of afforestation projects from productive forestry to forestry for environmental and social purposes. As an example, one fifth of the Danish municipalities plan to afforest some areas in the next 5 years, for example to attract new inhabitants. The attractiveness and values of afforested areas have been investigated in two independent Danish studies. In the first study qualitative and quantitative surveys in two municipalities indicated that forests improved the quality of life of the respondents. A short distance from the residence to the nearest forest usually resulted in a higher frequency of forest visits and a more positive view on the natural qualities of the local area in general, compared to respondents living further from forests. Proximity to nature, including forests, was furthermore mentioned as the most important reason for choice of their present home by 17% of the respondents. These results are supported by the second study in which housing prices were used to bring out the residents' valuation of forested housing areas. By using the hedonic price method homeowners' willingness to pay for proximity to forests was found to be significant and positive, and in most circumstances the aggregated value is expected to exceed the cost of afforestation.

Species composition

Throughout the region there has been increased emphasis on use of native species. This has been partly due to the decreased importance of productive forestry and partly due to increased concern about the use of exotic species. In Denmark there is now little natural forest left, and large parts of the forests are quite uniform and often with limited value for the protection of biological diversity and recreational purposes. Almost 37% of the forests are deciduous, while the remaining woodlands are planted with non-native coniferous tree species. A recent development during the last 10 years is that the fraction of deciduous forest is now increasing, whereas it used to be decreasing. This development is triggered through state afforestation, financial incentives and a negative development in soft-wood prices. The Danish forest cover is still increasing through public afforestation and private afforestation promoted through incentives. But still, Denmark is a relatively forest-poor country, with only around 0.1 ha of forest per capita, as compared to Sweden with 2.8 ha per capita.

The Norwegian forests are characterised by only two native coniferous tree species of commercial interest, Norway spruce and Scots pine. Early foresters claimed the need for introduction of more species. Among the first was Andreas Bull (1780) who wrote the book *An Attempt to Improve the Norwegian Forestry*.

The main reasons for introducing new species in forestry were the search for faster-growing species, species better adapted to an oceanic climate, species more resistant to pathogens, but also the idea of more exotic forests. About 50 tree species have been introduced through forestry in Norway covering today about 1% of the productive forest area (80,000 ha). However, only a few have been planted to a larger extent such as Sitka and Lutz spruce (55,000 ha), lodgepole pine (12,500 ha), larch (4,000 ha) and fir (3,000 ha).

In this connection the intensive afforestation of West Norway by native Norway spruce should also be included. The total area of plantations in Norway amounts to 3.6 million ha, of which 2.8 million is spruce.

In Iceland, many exotic species have been tried during the past 50 years. The period from 1950 to 1990 was a time when a great deal of experience was gained through experimenting with different exotic species and provenances. The main species planted were exotic conifers: Norway spruce, Sitka spruce, Scots pine, lodgepole pine and Siberian larch.

Afforestation in Iceland through planting has increased significantly since 1990 to over 6 million seedlings in 2004. Planting of native birch

has been “increasing”, comprising as much as 30% of seedlings planted in some years. Siberian larch is planted to roughly the same extent as native birch, followed by Sitka spruce, lodgepole pine and black cottonwood. These 5 species comprise about 90% of the seedlings planted in Iceland, with over 20 other species comprising the remaining 10%.

As in Iceland, many tree species have been tried in the Faroes. All of these must be considered as exotics as forest-forming tree species disappeared from the islands a thousand years ago. The most important coniferous species are Sitka spruce, lodgepole pine and larch. Many different broadleaved trees are used; amongst the most important are birch, alder, black cottonwood and rowan.

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Opposite page: The lake Saimaa, Finland. Photo: Edda Sigurdis Oddsdottir.

Effects of afforestation on wood production and forest yield

Bernt-Håvard Øyen and
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Introduction

From the first plantings and experiences in the afforestation areas in West and North Norway it became evident that there was a large potential for increasing the yield by changing tree species, especially from mismanaged broadleaves and pine to dense spruce plantations. The focal point in this chapter will therefore be the experience in Norway, with some examples from other countries.

Most Norwegian studies concerning the effects of changing tree species in reforestation areas have been conducted in neighbouring stands that offer similar growth conditions. The results from these studies (Table 2) contrast the results from mixed stands in South-East Norway and Sweden, where the growth differences between the tree species is less pronounced. About 85% of the reforestation areas in West and North Norway consist of Norway spruce plantations (approximately 250,000 ha), Sitka spruce (approximately 45,000 ha), and other conifers, including Scots pine, Douglas fir, larches and others.

Table 2. Effect of tree species conversion on site index (growth potential) and yield over one rotatic in Western Norway. Only a few of the most common tree species conversions are shown. The figur are based on data from Skogforsk.

Conversion	Gain in site index (H40 in m)	Gain in yield (m ³ /ha/yr)
Downy birch → Norway spruce	7–9	6–8
Scots pine → Norway spruce	6–8	4–6
Norway spruce → Sitka spruce	3–4	3–4
Downy birch → Scots pine	0	0
Downy birch → Sitka spruce	8–10	7–9
Scots pine → Sitka spruce	6–8	6–7
Scots pine → Japanese larch	6–8	4–6
Downy birch → European larch	6–8	4–6
Grey alder → Norway spruce	7–9	6–8

Growing stock in the afforestation areas has more than doubled since the 1930s and the annual increment is about three times higher. Presently, the 320,000 ha of natural Scots pine forests in West Norway have an annual production of about 2.5 m³/ha whereas the 165,000 ha of spruce plantations have an annual yield of about 7.9 m³/ha.

In the afforestation plans of the Forestry Commission the predicted yield of the spruce plantations was 5 m³/ha/yr. With a spruce plantation area of 275,000 ha, this would imply a future potential annual yield of about 1.38

Figure 7. Scots pine logs in eastern Norway. This species is one of the most economically important tree species in Scandinavia. Photo: Jon Geir Petursson.

million m^3 . However, in the yield tables for Norway spruce in West Norway the production has varied from 6.1 to 14.7 $\text{m}^3/\text{ha}/\text{yr}$, therefore 5 $\text{m}^3/\text{ha}/\text{yr}$ must be a minimum estimate. In new yield tables from Skogforsk the production in unthinned Norway spruce plantations has varied from about 6 to 15 $\text{m}^3/\text{ha}/\text{yr}$, these increments being attained in 100 to 60 years, respectively. In Sitka spruce the yield has varied from 12.0 to 32.0 $\text{m}^3/\text{ha}/\text{yr}$. The latest increment figures for Norway spruce plantations from the 1990s show 1.7 million m^3 . By applying yield figures of 8.5 $\text{m}^3/\text{ha}/\text{yr}$ in West Norway and 4.5 $\text{m}^3/\text{ha}/\text{yr}$ in North Norway the spruce plantations will yield a total of about 2.2 million m^3 per annum. It has been estimated that the yield from spruce plantations in West Norway would reach a potential harvesting level of about 0.8 million m^3 in 2020 and 2.7 million m^3 in 2060, although these predictions are highly dependent on the investment programs. Therefore, with a further stabilization of the spruce area, it seems likely that the spruce plantations in the afforestation areas will yield slightly more than 2.0 million m^3 .

The present annual harvested volumes are about 0.15 million m^3 in northern Norway and 0.25 million m^3 in western Norway, i.e. the potential for gradually increasing the cutting is substantial. The natural pine and broadleaves are having less economic importance in Norwegian forestry because 80-90% of the present commercial harvesting is taking place in the productive spruce plantations.

Benefits of afforestation

Worldwide, economic development theory provides a basic rationale for tree planting for both industrial and non-industrial purposes. In Norway the afforestation rationales can generally be confined to several factors, such as

increase of forested land and larger growing stock, environmental or social benefits, stimulation of local economy and multiplier effects.

Increase of forested land and larger growing stock

More wood resources offer more possibilities and flexibility for wood-using industries; adding industrial value in the forestry sector, and will also strengthen the farmers' possibilities for higher income and maintaining a rural way of life.

Afforestation and forest resources influence the real estate market. A property with great wood resources is far more valuable than properties without any woods.

The national economic rationale may also be confined to import substitution, less dependency on imports or generation of greater export income.

Environmental/social benefits

There are several environmental and social benefits to be gained by afforestation, i.e. storage of carbon, soil and water protection, snow and slope stabilization, windbreaks, less pressure on natural forests and promotion of outdoor activities and public health.

Stimulation of the local economy

Subsidizing tree planting in larger reforestation programs will increase government income from taxes and stimulate the demand for labour, for instance through forest nurseries, transportation, services and management.

Figure 8. Wood products are more than just paper and timber. Scandinavians have long tradition of local use of wood. This traditional fench in northern Sweden is a good example for alternative use. Photo: Jon Geir Petursson.

Multiplier effects

Afforestation will offer “multiplier effects” by stimulation of labour in other sectors: services, road construction, trade, etc. Norwegian studies from the 1970s revealed that one worker in the forestry sector provided occupation for 1.3–1.9 employees in other jobs. With a lower level of labour involved in forest management, it is likely that these effects have decreased during the last few decades.

In the 1950s the basic objective in afforestation was to maximize financial returns from real estate assets through wood production and the exploitation of commercial opportunities, using private capital wherever it was appropriate. Investment decisions were primarily made on the basis of discounted net benefit. However, state investments in intervention in afforestation areas could barely be justified by commercial returns alone but were also dependent on environmental and social benefits. Other outputs have become increasingly important. A recent study showed that British forests generated non-market benefits equivalent to £1,000 million per year. Although the population is less dense in Norway, considerable non-market values are also generated here. Optimum investment and management strategies in afforestation areas are still poorly understood – since the works are intermixed with other societal activities. Complex plantation forestry in reforestation areas, designed to maximize social benefits rather than wood production, are still under development in Norwegian afforestation areas – as in afforestation areas elsewhere.

Since most plantations were established in the 1960s and 1970s a large increase in harvestable volume is expected around 2020. In the meantime a wide range of policy tools should be considered to increase the benefits

Figure 9. Sawmill in eastern Norway. Wood processing contributes significantly to the economy of the Nordic countries. Photo: Jon Geir Petursson.

from afforestation: i.e. further investments in infrastructure, management options and silviculture for new or prolonged rotations, restoration and better combined land use, management of plantations to optimize their value as wildlife habitat, increasing the vitality of small scale companies, etc.

Challenging times lie ahead. International competition will maintain pressure on timber prices for the foreseeable future, commercial tree planting shows no sign of abating, and increasing demands on forests to meet social and environmental objectives will challenge current approaches to forest management. A crucial question is how to affect rural business activities in a positive way to ensure a more efficient outcome of afforestation programs. This field deserves further research and development in the future. All things considered, an optimistic view of the forests in the afforestation districts seems to be fully justified. Throughout history it seems hard to identify any cultures that have faced large problems caused by a surplus of commercially interesting forest resources. However, greater importance should be made in the future on the incorporation of ecological and esthetical aspects into the planning phase of afforestation.

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Opposite page: Moss campion in Iceland. Photo Edda Sigurdis Oddsdottir.

Effects of afforestation on biodiversity

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Introduction

Recently, there has been increased emphasis on conserving biodiversity, threatened habitats and ecosystems in the Nordic countries. The Nordic countries have signed the Convention on Biological Diversity, thus embracing the target of halting the decline in biodiversity by the year 2010. Therefore it is important to identify the effects that afforestation has on biodiversity and the functioning of ecosystems.

Afforestation causes fundamental changes in ecosystem structure and functioning, including changes in shading, the micro-climate, production, nutrient cycling and the water balance, all of which may affect biodiversity. It is well documented that conversion from treeless landscapes to forests can have negative impacts on organisms adapted to open habitats. In this context, most research has focussed on vascular plants and birds. Within the AFFORNORD project special attention was therefore paid to soil fauna, which constitute a group that has often been neglected in such studies.

Recently, the effects of afforestation on biodiversity were studied in Iceland, the Faroes, Sweden, Denmark and Norway in research projects connected to AFFORNORD. In these projects, areas afforested with native or exotic species were compared to non-forested areas. The focus was on important functional groups in the ecosystem, i.e. vegetation, fungi, invertebrates and birds.

Figure 10. Gap fraction indicates amount of light that reaches the forest floor, the higher the fraction the more light. Results from Iceland show that the number of plant species decreases when availability of light decreases.

Case studies linked to AFFORNORD

Vegetation

It is well demonstrated that ground vegetation in forests is influenced both by the tree species and stand density. Reduced light availability and changed nutrient cycling are the most important mechanisms which influence the species composition of ground vegetation. Research in Iceland has shown that relatively species rich vegetation communities of open heathlands will not persist long following afforestation. The number of plant species increases during the first years after afforestation, but eventually shade tolerant plant groups, such as horsetails, monocots and forbs, replace the original heathland communities and the number of vascular plant species is reduced. The open heathland and the young forest stands are relatively rich in species of mosses and lichens compared to the older forest stands.

At the thicket stage of a coniferous forest stand, the ground vegetation is characterized by low plant cover and species diversity, but after thinning the plant cover and diversity increases slightly. In general, the cover of vascular plant species, mosses and lichens decreases following afforestation. At the same time there is a significant change in the relative proportions of many of the species present. These changes following afforestation were

Figure 11. Plant species in young Sitka spruce stand in Iceland are common heathland species and adapted to the open habitats, e.g. viviparous fescue, northern bedstraw, heath wood-rush, shady horsetail, alpine bistort, lady's bedstraw and wild thyme. Photo: Asrun Elmarsdottir.

Figure 12. Vegetation in a dense 45 year old lodgepole pine stand in Iceland is sparse and few plant species grow there, e.g. wavy hair-grass, shady horsetail, wood crane's-bill, stone bramble and sheathed sedge.

Photo: Asrun Elmarsdottir.

mainly found to be due to decreased light at the level of the forest floor. This was also shown in a study in Denmark where the number of herbal species in oak forest increased rapidly after heavy first thinning.

Comparison of native broadleaved forests to afforested coniferous plantations shows that species richness of vascular plants is considerably higher in native broadleaved forests. Both in the Icelandic and Norwegian case studies, the highest number of vascular plant species was found in mountain birch forests, while coniferous plantations (Norway spruce, Sitka spruce, Siberian larch and lodgepole pine) contained fewer species. Also, species richness of vascular plants is affected by coniferous species. This difference is mainly due to the amount of light which reaches the forest floor. Similarly, understorey biomass is related to the amount of light. Therefore, a more open canopy leads to a greater diversity of plants and more ground vegetation biomass. Species richness of vascular plants can therefore be affected by forest management (stand density and thinning regime) and choice of tree species.

Figure 13. Hallormsstadur, East Iceland. An old-growth birch forest with diverse vegetation, for example wavy hair-grass, bog bilberry, horstail and stone bramble.

Photo: Asrun Elmarsdottir.

Fungi

Afforestation increases organic material in the ecosystem, which is eventually decomposed by bacteria and fungi via the production of a vast array of extracellular enzymes. The fungal biomass can often exceed that of other microbes, plants and animals in the ecosystem and the fungi represent a significant portion of the ecosystem nutrient pool. Fungi also form essential symbiotic associations with tree roots, namely, the mycorrhizas. Mycorrhizas supply the trees with water and nutrients, such as nitrogen and phosphorus, in exchange for a supply of carbon. The larger part of the fungi live underground as mycelium and many species are confined to that life form. However, some fungi form fruitbodies (i.e. mushrooms) aboveground.

Research on fruitbody diversity in Icelandic forests has shown that older native forests and plantations have a higher number of fruitbody forming species than heathlands or younger and more open plantations. Higher numbers of fungal species living on decaying wood were found in older forests. However, since many species of fungi do not form fruitbodies, fungal biodiversity is therefore reflected not only by the number of fruitbody forming species. Research on mycorrhizal types found on tree roots indicates that both the biodiversity and biomass of mycorrhizal fungi increase

Figure 14. Fungi in forests live in various habitats. Top left is *Paecilomyces farinosus*, an insect pathogenic fungi, top right is the fruitbody of *Chalciporus piperatus* that forms mycorrhizae with trees and bottom left is a mycorrhizal root tip of birch (*Hebeloma* sp.). Photos: Gudridur G. Eyjolfssdottir (top) and Edda S. Oddsdottir (left).

following tree planting on open land, but as the forests grow older, the number of mycorrhizal types and the biomass of mycorrhizal fungi partly decreases. In Iceland, afforestation seems to increase fungal diversity and biomass in a similar way, whether native or exotic tree species are used.

Soil invertebrates

Mineralization of nutrients is governed directly by the activities of bacteria and fungi. The ability of microbes to do this, however, is affected strongly by soil animals as they fragment and mix the organic matter in the soil. In general, earthworms are considered to be good indicators of soil quality as they demand good soil conditions. An Icelandic case study showed that more earthworm species were found in young plantations and native birch stands than in open heathland, older forests or exotic coniferous stands.

The case study in Iceland showed that the species richness of collembola increased as heathlands were converted to forests, irrespective of forest type. In an AFFORNORD related survey, 49 species of collembola were found in Icelandic birch forests whereas conifer plantations had 31 species and a lower proportion of habitat specialists. The AFFORNORD survey led to discovery of many new species and the total number of collembola species known in Iceland is now around 160 or almost a 100% increase from

Figure 15. *Parisotoma notabilis* (top left), *Lepidocyrtus lignorum* (top right) and *Protophthora pseudovanderdrifti* (bottom left) are common species in Icelandic forest soils. Photos: Arne Fjellberg.

earlier numbers. Five new collembola species were found in the Faroes.

In Iceland similar collembola species and species dominance are found in birch and exotic conifer forests whereas in Norway the birch forests differed strongly from coniferous forests, both in species composition and dominance. It appears that collembola from the native Icelandic birch forest soil establishes in exotic coniferous soils with only small adjustments. In Iceland, afforestation seems to increase soil faunal diversity regardless of whether native or exotic tree species are used. In Norway, in contrast, there are marked differences between the two forest types.

Surface invertebrates

Invertebrates living on the soil surface, such as spiders and beetles, are mainly predators on other invertebrates or soil fauna. Some take part in decomposition of organic material or feed on vegetation or fungi. The trees themselves provide habitat for many species of invertebrates, but this element of the fauna is not included in the discussions below.

In the Icelandic case study, the total number of invertebrate species living on the soil surface is similar for the different habitat types, i.e. heathlands, native birch forests and exotic coniferous stands, but species composition is radically different.

Figure 16. Invertebrates collected in a pine forest in Iceland. Photo: Erling Olafsson.

The surface invertebrate fauna that characterize heathlands disappear as conifers are introduced and new invertebrate species colonize the area. The changes come in certain stages. For young coniferous plantations the surface fauna is similar to a heathland fauna. Later, at the thicket stage, the surface invertebrate fauna in conifer stands is very different from both the fauna of birch forests and heathlands. Common surface species in conifer forests need humidity, which comes with the shade provided by the trees, and find a suitable habitat in the sparse undergrowth of conifer plantations. However, the surface invertebrate fauna of Siberian larch forests retain similarities to the birch forests, probably because larch is deciduous.

Avifauna

The avifauna of the Icelandic heathlands is characterized by meadow pipits, rock ptarmigan and some few species of waders, the most prominent being golden plover, whimbrel and snipe, and in wetter areas godwit, dunlin and redshank are also common.

In the Icelandic case study, no major changes took place with regards to the avifauna during the first 10 years of conversion from heathlands to exotic coniferous plantations. Open country birds still dominated the scene but the first forest birds had shown up, i.e. redwing and redpoll. By the

Figure 17. Golden plover is one of the bird species that is characteristic of the open land in Iceland. Photo: Hrafn Oskarsson.

time the stands were 20 years old and had reached the thicket stage, all the specialized open country birds had disappeared; golden plover, whimbrel, godwit, dunlin and redshank. The avifauna of these stands was composed of generalists, species that live both in heathland areas and forested areas such as snipe and meadow pipit, and forest birds, redwing, redpoll, wren and goldcrest. No major changes with respect to the avifauna occurred during the next 30 years in the life of the coniferous stands.

This shows that the changes in the avifauna from heathland to forest-dominated avian fauna takes place primarily between a plantation age of 10 and 20 years. Total densities, measured as territorial pairs per unit area, also change as the plantations mature. Common figures for heathland areas are 100 pairs per km². Breeding densities are much higher in older birch and larch forests areas with 300–500 pairs per km². However, avian species richness is similar in heathlands and older forests.

Comparison of the avifauna of the non-native larch stands and the native birch forest shows that the source for settlers with respect to the larch stands is local, but not without exception. All the common birds within the larch stands are also the species characteristic of the native birch forest avifauna. The only exception is the goldcrest, which is native to coniferous forests in Europe and Asia. It was known as a vagrant in Iceland until 1995, when large numbers arrived, and subsequently goldcrests started breeding.

Figure 18. The redwing is the most common forest bird in Iceland. Photo: Hrafn Oskarsson.

Within a few years the species colonized coniferous and larch stands all over Iceland and even penetrated the native birch forests. The goldcrest in Iceland is a good example of long distance dispersal and the power of exponential growth: the smallest bird species in Europe, here locating newly created pockets of habitats on an island isolated in the middle of the Atlantic and becoming within 10 years one of the most common forest birds. It is unlikely that more native bird species will settle in the forest stands; rather, any addition will be a species from abroad, as in the case of the goldcrest.

General conclusions

The general conclusion from the different case studies clearly indicates that afforestation affects species richness of different functional groups in different ways.

- The number of species of vascular plants is negatively affected by afforestation. Shade tolerant plant groups replace the original heathland communities.
- Fungi and soil invertebrates respond to afforestation with an increase in species richness.
- The total number of surface invertebrate species is similar for different habitats but species composition is radically different.
- The total number of bird species is similar between habitat types, but major changes take place in species composition and breeding densities.

Species richness of many groups can be affected by forest management (stand density and thinning regime) and choice of tree species.

Afforestation strongly affects species composition in all functional groups. Generally, some species disappear and others colonize the new habitat. These changes are also affected by the tree species and management regime selected. It is therefore very important to include strategies for conservation of biodiversity in forest planning and management in order to preserve areas that contain special habitat types or rare species.

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Modelling ground vegetation changes

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Introduction

Ecosystem development is affected by many factors. Whenever we encounter very complex situations, one of the methods to analyse cause and effect is to carry out system analysis and construct system models. Simplification is always required to make such predictive models.

The ForSAFE-VEG model was adapted and redeveloped within the AFFORNORD project group to simulate changes in the composition of the ground vegetation and used to investigate different possible future outcomes of different policy options. The model simulates the interaction between the trees, the ground vegetation, the soil, the physical, geochemical and climatological conditions at the site, and management (thinning, harvesting, and fertilization) of the forest.

A conceptual picture of the terrestrial ecosystem components, as elaborated by the AFFORNORD group, is shown in Figure 19, showing the causal chain from afforestation to the effect on ecosystem development and the quality of the human habitat and standard of living. The figure represents the general understanding of the system, and the part in black gives what is modelled in the ForSAFE-VEG model.

The ground vegetation composition in the ForSAFE-VEG model is based on the occurrence of key plant groups. Each of the key groups is assumed to have a specific response to moisture, temperature, nitrogen, chemistry and shading. Based on the specific responses of the key groups to the conditions as simulated by ForSAFE, the VEG module calculates the relative occupancy of the key groups with respect to the others, and a fraction of the forest floor area is assigned to each group. The ForSAFE-

Figure 19. Conceptual picture of the biodiversity components in a terrestrial ecosystem. Interpretation of the major expected responses according to the mental model illustrated, defined for biodiversity in the AFFORNORD project. Black indicates parts that are modelled in the ForSAFE-VEG model.

VEG model predicts changes in vegetation structure based on the modelled changes in the present physical environment. The responses are, however, not instantaneous but rather delayed by key group-specific time.

The case studies selected

Two sites with the largest possible contrast were chosen from our AFFOR-NORD case studies, one in southern Sweden and one in eastern Iceland.

The Söstared site is located in southern Sweden near the coast. It was originally covered by nemoral beech-oak dominated forest. In ca. 1650 it was cleared for sheep pasture and stayed treeless for approximately 300 years. The open land was repeatedly burned for heather clearance and the soils became quite denuded in mineral substrate through erosion. The area was afforested with conifers in 1920-1940. The climate is mild (average annual temperature 6.5 °C), slightly windy on open land and with little snow in the winter. Rainfall amounts to about 1100 mm per year.

The Hallormsstadur site is located in eastern Iceland, an area that had mountain birch forest at the time of the Norse settlement in the late ninth century and that was gradually denuded to disappearance by ca. 1650. The land remained open and was used for sparse sheep grazing until it was afforested in 1952. The surrounding area was used for afforestation during the period 1950 to 1990. The climate is cold temperate (annual average 3.4 °C) and windy on open land (average wind speed 7 m/s). The site has episodic snow cover during the winter.

Figure 20. Predicted changes in occurrence of key plant groups at Söstared. The model fits reasonably with observed data and we may therefore expect it to give reasonable predictions. Grey: lichens and mosses; Blue: dwarf-bushes; Yellow: grasses; Red: brackens and ferns; Green: herbaceous plants; Brown: bushes and bush-like thickets.

Model outputs

The sites have to a varying degree been without forest cover and the results of the model show the particularly large effect of deforestation and subsequent afforestation on the occurrence of key plant groups (Figures 20 and 21).

The first change of ground vegetation at Söstared was caused by a forest fire in the 15th century (Figure 20). The second large change was when the area was cleared and grazed. After 1900 it was afforested. However it is now under conditions of intensive forestry and increasing input of nitrogen deposition (see chapter on carbon sequestration). From now on, even small forestry changes will result in large effects on the composition of the vegetation, largely because of the considerable availability of nitrogen. Possibly also the increase in annual average temperature as caused by climate change is playing a role in making the site more dynamic in its responses.

In the response for Hallormsstadur, during the period 1900–2100, the model predicts similar or increased key-species richness after afforestation in 1952, which is only partly supported by data presented in the present book (see previous chapter on biodiversity) (Figure 21). This might be attributed to improved forest climate at the exposed site and improved nutrient status due to the enhanced forest nutrient cycling. The model is also successful in predicting observed changes in the amount of ground vegetation, which decreased after the forest canopy was established (see chapter on biodiversity) (Figure 22).

These model results, however, do not show the downward trend in vascular plant diversity in middle-aged stands measured in the case studies at these same sites in Iceland. This discrepancy may be explained by the time lag in the real world for new species to colonize a new suitable habitat. The shade-adapted vascular plant species found in the vicinity of the Hallormsstadur site may not have had time to colonize the afforested areas. Further development of the ForSAFE-VEG model will consider distributional patterns of vascular plants.

Figure 21. Predicted changes in occurrence of key plant groups at Hallormsstadur (Iceland). Grey denotes lichens, blue-violet heather, yellow grasses and hatched ferns, other colours denote bushes and herbs.

Figure 22. Comparison between measured and observed changes in the amount of ground vegetation at Hallormsstadur, Iceland.

Conclusions on modelled ground vegetation changes

The model showed significant effects of afforestation on vascular key plant group composition. The modelled effects are both positive and negative.

The model showed that introduction of the tree canopy changed the ground vegetation by changing access to light and nutrients. At the nutrient-rich site (Söstared) this led to a net loss of plant groups, while at the nutrient-poor site (Hallormsstadur) more plant groups could occupy the site.

Under conditions of exposure to strong winds, such as at Hallormsstadur, the introduction of a tree canopy can break the wind and provide winter shelter that allows colonization by certain plants that would not survive in an open landscape.

In the south of Scandinavia, afforestation can cause more pollution (acidity, nitrogen, ozone) to reach the ecosystem, with significant effects on biodiversity. Such effects do not take place where high atmospheric deposition does not occur, as at the site in Iceland or in parts of northern Scandinavia.

The vascular plant biodiversity reached (here based on key plant groups) may be partly directed by choosing the proper management method and appropriate tree species. Policy value judgements are needed in deciding the total benefit or loss of such actions.

Many questions remain unanswered, but the ForSAFE-VEG model provides a powerful tool for studying future options in afforestation. The

ForSAFE-VEG is undergoing continuous development, at the moment being applied to 32 sites in Switzerland and 20 sites in Sweden as an ongoing study for assessing ground vegetation changes as affected by acid rain, nitrogen pollution, climate change and management changes within the UN/ECE-LRTAP convention. The model is at present being used in 5 different countries in Europe for this purpose. This has further emphasized the value of having access to at least one site in Iceland where the air pollution is near to background values.

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Opposite page: Skorradalur, west Iceland. Photo: Bjarni D. Sigurdsson.

Effects of afforestation on landscape and public health

Audur Sveinsdottir, Anna Maria Palsdottir
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“Landscape” means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.

European Landscape Convention

Introduction

Is there an impact of afforestation on landscape, and – if there is – what is the influence, what are the consequences and what are the possibilities to work with?

The geological history of an area constitutes the basis for the landscape to extract and discuss some of the main aspects of the interaction between landscape and afforestation. In this chapter we will discuss different views on the subject and suggest actions to improve afforestation planning in context with the concept of landscape.

The definition of landscape is variable and has various expressions in the Nordic countries. The landscape as a physical phenomenon is used in connection with nature and cultural environment, but refers also to the dynamics of the landscape and visual aspects and topography.

The definition of landscape is also variable within different cultures and societies, and even within the same society. As an example, there are at least 40 different definitions of the concept “landscape” in Finland. The following quotation from Jala M. MakHroumi of the University of Beirut in Lebanon is an example of different perception of landscape in different countries and cultures:

The contemporary Western way of seeing landscape as view of the countryside is alien to the cultures of the Middle East for several reasons. In the hostile environment of the Middle East, comfort and security and, by association, beauty, are embodied by landscapes that are human-modified and human-made, the agrarian landscape and the urban one respectively. It is understandable, therefore, that the focus of aesthetic appreciation is not the outlying landscape of hills and forests, but a cultural one, in which nature has been ‘tamed’, enclosed and ordered.

In Iceland, the perception of landscape has changed dramatically during recent decades. Formerly it was more connected to the livelihood of people and their basic industries, not so unlike the Middle East perception. Presently, this view is changing and new concepts of landscape are becoming more common, e.g. urban, industrial and cultural landscapes.

Now, most European countries have adopted the European Landscape Convention, which embodies increased understanding of the importance of the landscape.

Figure 23. Naturally regenerated European larch at Tingvoll, Norway. Photo: Per H. Nygaard

Why a landscape convention?

The landscape ...

- ... has an important public interest role in the cultural, ecological, environmental and social fields, and constitutes a resource favourable to economic activity and whose protection, management and planning can contribute to job creation;
- ... contributes to the formation of local cultures and ... is a basic component of the European natural and cultural heritage, contributing to human well-being and consolidation of the European identity;
- ... is an important part of the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as in areas of high quality, in areas recognised as being of outstanding beauty as well as everyday areas;
- ... is a key element of individual and social well-being and ... its protection, management and planning entail rights and responsibilities for everyone.

European Landscape Convention

Various methods can be used to assess the effects of afforestation on the landscape. In this project certain key aspects of the landscape were evaluated to build this assessment on. The combined evaluation is based on all those those key aspects. This method is part of landscape analysis and is used when dealing with larger areas where major changes are predictable. In this chapter we will focus on the following factors:

- geodiversity
- cultural heritage
- aesthetics
- environmental identity
- recreation and health

Geodiversity

The geological history of an area constitutes the basis for the landscape variation we find within the area. The term “geodiversity” has been defined as “the complex variation of bedrock, unconsolidated deposits, landforms, and processes that form landscapes”. Geodiversity affects biodiversity and provides the foundation of both natural and cultural landscapes. Protection of geodiversity is an integral part of nature protection in most countries, even if the term itself has a rather short history. Geodiversity is important in the every-day landscape in relation to education, recreation and consciousness of nature and ecological functions. Landscape planning is an important tool for protecting geodiversity, but legislation and management practices vary among the Nordic countries. With respect to afforestation, aspects of geodiversity have not been among the most important in afforestation planning.

Geoconservation is important for several reasons, e.g. for preserving examples of past life forms and evolution, for biodiversity, for leisure industry and for research and training of future scientists. It is also important for historical and cultural reasons.

Geology and protection of geodiversity vary within the Nordic countries. In Denmark, more than 200 national geological sites are protected and approximately 170 in Norway where few thematic conservation plans have been made for specific geological features. However, during the afforestation of West and North Norway in the 1950’s and 1960’s, no geological or geomorphological considerations were included.

In Iceland, the geology is very different from that of the other Nordic countries. Iceland’s first Nature Conservation Act was enacted in 1956. When the Act was revised in 1971, seven of the ten existing protected areas were mainly for protecting geodiversity. Since then, more than 300 localities have been registered as valuable for nature conservation, and many of

Figure 24. Many aspects in the afforestation-geodiversity interface coincide with those of visual aspects and cultural heritage.

Photo: Lars Erikstad

Figure 25. Special geological formations, such as Icelandic lava fields, should not be considered for afforestation. Photo: Audur Sveinsdottir.

these can be characterised as geological sites. During afforestation planning in Iceland, specific geological sites, such as recent lava formations, are excluded from afforestation.

Afforestation affects geodiversity in different ways. It may cause loss of view and landform visibility, since forests often cover vast areas, including geological formation. Afforestation may cause physical damage to small-scale landforms and stabilize dynamic landforms.

Recommendations

- Plan open spaces and maintain open views.
- No planting in gullies, craters, lava fields and important geosites.
- Geodiversity should be included in environmental impact assessment, planning and nature management at all levels.

Cultural heritage /cultural landscape

Figure 26. Every landscape is a cultural landscape because the influence of man is all over the globe, in some places completely dominating (to the left) in other places hardly noticeable (to the right). Photos: Audur Sveinsdottir and Hrafnhildur Hannesdottir.

Today's landscape is to a large extent the result of human activities in the past. Our cultural heritage can be read from the landscape, partly by remnants of human structures (cultural heritage sites), but also from the structure of the landscape itself. Therefore, acknowledging landscape as a cultural heritage suggests a need for its conservation, in afforestation planning as in every other land use.

The question is: what kind of landscape do we want to take care of and how? We have to come to an agreement on what is valuable for protecting and managing.

Afforestation can cause irreversible changes to cultural heritage and can be a serious threat to archaeological sites. In the Nordic countries, there are different guidelines on how close to archeological sites trees may be planted. Archeological authorities in Sweden and Norway can require a certain unplanted zone around archeological sites and in Denmark planting is not allowed within 150 m from grave mounds. In Iceland, the idea of landscape as part of the cultural heritage is reflected in the current antiquity legislation. It is made a part of afforestation guidelines that forests should not be planted within a certain distance from such sites, but this is not backed up by legislation or regulations.

There are several dangers that threaten cultural heritage and they can cause irredeemable changes.

In the future, forestry will probably be the largest threat to old relics in rural areas, since vegetation will cover remnants, making them difficult to see and also because larger machines that convert the land are being used in forest management.

Niku Tema 16

Figure 27. Pasture and "salmon river" landscape in North Iceland. Photo: Audur Sveinsdottir.

Figure 28. Along the coastline of western Europe, treeless heathland is the man-made cultural landscape bordering the Atlantic Ocean. Here from Heathland centre at Lygra, Norway. Photo Audur Sveinsdottir.

Recommendations

- It is necessary to develop methodology that suits each place at each time and to establish consensus about protection, preservation and tending of cultural heritage.
- Review laws and regulations concerning cultural heritage.

Aesthetics

The term *aesthetics* comes originally from the Greek *aesthenesthai* "to perceive", and *aisthet* "things perceived", in this case using our eyes.

Landscape is affected by use of land, including afforestation, which determines the patterns of vegetation. There is a great contrast between forests and open ground in the landscape, and major landscape changes in our times have been brought about by the establishment of woods and forests.

Figure 29. Ruins of an old sheep stall at Höfði in East Iceland, surrounded by young larch which has been planted at a certain distance from the ruin.

Photo: Thröstur Eysteinnsson.

Peoples' perceptions of aesthetics are variable; depending on individuals, time, circumstances and culture:

From being a controversial activity, plantation forestry has become an accepted element of the British landscape. While some of this acceptance might be accounted for by the fact that several generations of people have grown up with these forests, a considerable amount of credit is due to the role of good landscape design in helping to blend these forests into the wider landscape.

Bell, 2007

In western and northern Norway afforestation was mainly performed on private ground. The plantations are therefore often restricted to the limits between properties. In most Norwegian municipalities, the effort was planned with the aid of local forest authorities, but the choice of areas was mainly based on forestry considerations. No explicit landscape considerations were included, neither in Norway nor in Iceland. The result is that the plantations are often seen as landscape elements with sharp, straight borders; similar to those described for Scotland.

However, more consideration to the landscape is taken today, though further improvements are needed. In Denmark a landscape character method has been developed to recognise different landscape types, based on history, culture, space, landscape completeness and the protection of the natural environment. On basis of these characteristics large areas for afforestation are divided into three categories; a) areas where afforestation is encouraged; b) areas where afforestation is prohibited; and c) areas where afforestation is neither encouraged nor prohibited. In the UK it is recommended that the aim of landscape design, previous to afforestation, should be to: a) reflect and enhance the best natural qualities of the landscape, as seen from

Figure 30. Leggjabrjotur, an ancient path between West and South Iceland: here passing through a mixture of birch and exotic conifers. Photo: Audur Sveinsdottir.

Figure 31. Tumastadir, South Iceland; mixed conifers, newly planted in a square block. No effort has been made to blend the plantation into the surrounding landscape. Photo: Audur Sveinsdottir.

relevant viewpoints; b) incorporate natural features and detail, eliminate visual intrusion; c) assist in development of wide range habitats; and d) meet the operational needs of efficient woodland management. Similarly, in the Scottish “Forest Landscape Design principles” there are 6 key design principles: a) shape, b) scale, d) unity, e) visual force, f) diversity and g) spirit of the place.

Recommendations

- Aesthetical prerequisites should be considered when planning afforestation.
- Elaborate specific methodology and a guidance of good practice concerning aesthetical view and visual effects of afforestation on landscape should be formed.

Figure 32. Ölkofradalur, a historic place at Thingvellir is hidden in a spruce plantation. Photo: Audur Sveinsdottir

Environmental identity

According to the European Landscape Convention, each party undertakes:

- *to recognise landscapes in law as an essential component of people's surroundings, an expression of the diversity of their shared cultural and natural heritage, and a foundation of their identity;*
- *to establish and implement landscape policies aimed at landscape protection, management and planning through the adoption of specific measures;*
- *to establish procedures for the participation of the general public, local and regional authorities, and other parties with an interest in the definition.*

European Landscape Convention

Landscape identity is a part of the environmental identity, where an individual defines internal subjective and cognitive concepts of oneself in relation to the physical environment and reflects the belonging one feels within that particular context. This process has its roots, beginning at early age and is a lifelong learning process, affected by people's background and life experiences and most likely has a considerable effect on one's affection for and identification with the environment. Therefore landscape identity and recognisability are basic elements of the quality of living places and directly linked to the quality of life of populations and loss of the latter can often be associated with loss of landscape identity and of the feeling of belonging of local populations.

Figure 33. Every place/country has its own identity and character. The identity of Mt. Hekla, South Iceland, is rooted in old legends where it was supposed to be the entrance to Hell.

Photo: Audur Sveinsdottir.

Figure 34. Hraunfossar; West Iceland. Artists are inspired by landscapes and in the book “A Giant Love Story” by Gudrun Helgadóttir, the falls are pictured as the milk of a giant woman. Photo: Kjartan Kjartansson.

The spirit of a place (*genius loci*) is an important part of its speciality. Legends and adventures are often rooted in the landscape and used to explain extraordinary landscape features. In Iceland, perception of the landscape often developed into strong belief in supernatural forces and extreme feelings for the unknown and this is often reflected in place names. Therefore, each person's perception of the landscape is related to the history and culture of each society as well as personal background and feelings. Consequently, it is important to activate these skills at an early age in order to ensure that our youth develop environmental identity and a sense of nature.

Recommendations

- It is important to register and preserve folk beliefs, arts and cultural history that relate to experience and perception of landscape.
- Laws and regulations need to be adjusted to ensure that the specific character of each area is maintained as recommended in the European Landscape Convention.

Recreation and health

Nature provides us with essential resources for our survival as well as being of importance for our health and well-being. Many studies have found a relationship between nature experiences and positive effects on our social, mental and physical health. Most often, people seem to react more positively to a natural environment than to urban sites.

But, why do people feel good in natural environments? Within environmental psychology two dominating theories seek to explain the positive effects of nature on humans. One is presented by Roger Ulrich and the other by Steven and Rachel Kaplan.

Ulrich's theory, *Biofilia*, is based on our inherited evolutionary and genetic memory of the original environment humans used to live in. We feel safe in natural surroundings because we are adapted to these kinds of environments and they therefore reinforce positive feelings. This is a basic and universal physical response.

The Kaplan's theory is called *Attention Restoration Theory (ART)* and is based on the fact that the human brain has two kinds of attention: directed attention and soft fascination. The urban environment is overloaded with information that has to be sorted out and processed. For this demanding process, directed attention is used and is very energy consuming. In nature we do not have the same amount of information flow that has to be processed. This allows us to use soft fascination. The process does not demand energy and our capacity is unlimited, resulting in a restorative state of mind and body.

In addition to the above-mentioned theories, Searls' relation theory argues that nature plays an important role in people's well-being. The relation to nature and natural objects such as water, stones and plants is simple and not demanding but the relation between people is more complex and demanding. Therefore, nature offers possibilities for recreation and to relax, hence reducing the level of stress. A forest is an ideal alternative for offering varied nature experiences and reloading one's mental and physical strength

Figure 35. The water is attractive, especially to the young. Kjarnaskogur forest North Iceland. Photo: Auður Sveinsdóttir.

since such an environment only requires spontaneous concentration.

Nature preferences seem to be very similar within the Scandinavian countries, people prefer landscape variation with natural characteristics.

- Most people prefer forests and nature with a rich variation of flora and fauna.
- The presence of lakes and rivers is highly favoured both in open landscape and forest sites.
- Many people like elevated landscape and the possibility of overviews of the surroundings.
- In the forest, a combination of moderate natural walking paths is wanted so the different forest areas can be easily accessed.
- Access is also related to the forest density; too dense forest can be both mentally and physically difficult to access. Too dark and dense a forest area with low visibility is considered by many as not a safe environment.
- A light and bright landscape, dominated by broadleaved trees, with open spaces, is considered safe.

The distance to a park/nature site is of importance. Both Swedish and Danish studies have found a correlation between distance and frequency of visits. Those who live close to a recreation site actually visit the site more frequently. A connection was also found between the frequency of visits and one's perceived level of stress i.e. persons frequently visiting parks and nature sites feel they are less stressed than those who visit the parks less frequently.

Figure 36. Icelandic birch forests are popular for various outdoor activities. Here, a group of school children walking in the Thorsmörk, South Iceland. Photo: Þröstur Eysteinnsson.

Presently, more and more people choose to live in cities and the daily access to nature decreases, both in terms of distance and time. In the long term this can have serious consequences for the individual's health as well as for society as a whole. Therefore, contact with nature is necessary in the ever faster growing urban society. This demands proper planning in close relation with the general public. It is also important to execute this in harmony with the surrounding landscape.

Recommendations

- More research on the effects of outdoor activities on health is needed.
- Based on results from such studies, it is important to elaborate specific policy on outdoor activities, both on a district and a national scale.
- Outdoor activities must be considered in planning afforestation, and legislation and regulations should take account of such needs.

Conclusions

Afforestation has a profound effect on the landscape. It is therefore necessary to assess and analyse the landscape in relation to afforestation planning and include knowledge regarding geodiversity and aesthetics. Furthermore, it is important to assess cultural sites in landscape and establish consensus on protection of those sites. They should be considered both as specific sites and also as part of the landscape. Forests should never be planted on geologically interesting sites, protected areas or too close to valuable archaeological sites.

The need for public participation and a multi-disciplinary approach in afforestation planning processes must be acknowledged. To do so, it is suggested that specific guidelines for use in afforestation planning, similar to those used in Denmark and Scotland, should be adopted and laws and regulations concerning afforestation need to take account of landscape effects.

Even though more information on the effects of afforestation on recreation and health is needed, the knowledge already available should be included in afforestation planning.

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Effects of afforestation on rural development

Jon Geir Petursson and Eva Ritter

The rural value of forests does not arise from their simple physical presence, but from their contribution to the rural quality of life and local identity.

Elands and Wiersum, 2003

Introduction

Forests are an important natural resource in rural areas. In the more forested Nordic countries (Norway, Sweden and Finland), forests have traditionally played a key role in rural economies and social identity. In less forested Denmark, reclaimed forests have become a significant issue of rural livelihoods, and the almost completely deforested Iceland is undergoing a significant forest transition where active afforestation programmes are increasingly transforming the denuded rural landscapes.

The role of forestry in the Nordic countries is subject to changes. It is no longer only about economy, but also about lifestyle and environment, both in the highly forested regions and in regions where forests are less abundant. These changes are due in part to an increase in forest cover following afforestation activities, but also to social changes among forest owners. The number of private and small-scale forest owners has increased, and many of them live in urban areas. The goals of rural forestry have been affected by the lifestyle of the new forest owners. Rural forestry today includes aspects of recreation, nature protection and other forest services that are related to the lives of the rural as well as urban populations and no longer stands primarily for timber production and environmental management.

Forest policy is considered a significant part of future European Union Policy on rural development. Since 1980 there has been a range of policies

Figure 37. Forests add significantly to rural identity in the Nordic countries, especially in Norway, Finland and Sweden. This art work is from Umeå in North Sweden, which claims to be “The City of Birches” (Björkarnas Stad). Photo: Jon Geir Petursson.

throughout Europe to expand the area of woodlands. A positive effect on rural livelihoods is expected, either by counteracting the increasing migration into cities or by providing new rural services that are demanded by a growing urbanized lifestyle in rural areas.

The Nordic countries provide important examples of various stages of afforestation or forest transition and their impact on rural development. Extensive parts of the Nordic countries consist of rural areas, and considerable political attention is given to the development of these areas. However, there are different experiences and opinions on how afforestation and forestry can contribute to rural development. In this chapter these issues will be discussed in the context of the Nordic countries.

Rural areas and their development

The difference between urban settlements and countryside has become less and less distinct in Europe. In many regions an improved infrastructure has made it possible for people to live in the countryside and work in cities, resulting in the urbanization of rural areas. The distinction between rural and urban areas has therefore become complicated, even more so within the Nordic countries where the characteristics and definitions of rural areas are very variable. When discussing afforestation as policy measures for rural

Figure 38. An increasing number of forest owners now live in urban areas. In many Nordic regions, the difference between urban and rural settlements is becoming less distinct. Denmark, being the most densely populated Nordic country, has many examples. Photo: Jon Geir Petursson.

development, it is therefore important to address the different definitions of the terms “rural areas” and “rurality”.

The definition of rurality can be based on different factors, involving quantitative as well as social dimensions. A pragmatic definition is to refer only to population density and size of settlements. This would ask for a cut-off point for density and settlement size that defines when a population density is low enough to be called rural. However, this cut-off point will vary highly among countries and even regions. Hence, the term rural is understood differently in different countries and societies, contrasted in the Nordic context between densely populated Denmark and sparsely populated Iceland. Therefore, it is important to realise the difficulty of providing a single objective definition of rurality.

Three definitions of the term rural are given by Elands and Wiersum (2001). Two of the definitions are based on rural as space and socio-spatial or socio-cultural parameters, respectively. The definition based on socio-spatial parameters uses common spatial descriptors of rural environments such as land use, population density and employment. The problem with this approach is that these parameters are not feasible for universal use since countries will demand different cut-off points for the minimum population density or employment rate. Furthermore, this definition does not provide much insight into the nature of the rural environments and is an attempt to fit a definition to what is already considered rural. Nevertheless, this definition can describe changes in the spatial descriptors that relate to effects of afforestation on community benefits. When quantifying the proportion of urban versus rural dwellers, a common cut-off point in the Nordic region is set at 200 inhabitants per settlement. However, when using this definition for the Nordic Countries, Iceland would be the most urbanized country in the Nordic group with around 94% of the population in urban settlements, contrasted with Norway which would then have the highest rural figure of around 25%.

The socio-cultural definition assumes a characteristic rural lifestyle opposed to the urban lifestyle, typically described as relaxed versus hectic or being close to or separated from the natural environment.

A third definition understands rurality as a personal perception and interpretation of everyday reality. Thus, this definition depends on the background of the person who observes the area; i.e. personal identity with the landscape. Urban people or new citizens in rural areas may be attracted by the beauty of the landscape and a more relaxed lifestyle, while farmers consider those areas rural where primary production is possible.

It is difficult to select one single definition in the discussion of the effect of afforestation. As we will see later in this chapter, the effects that afforestation and forestry have on rural societies are connected to socio-spatial and social-cultural parameters as well as the personal perception of the area by the inhabitants. Therefore, rurality is not only about population density, employment and primary production, but also about lifestyle, well-being and recreation.

Rural development

The most common goal of rural development policy is to strengthen the socio-economic livability of rural areas and to reverse the migration to urban areas. Afforestation is one of the measures employed to influence rural development and a strategy to reach the desired future state of the countryside. It is important to take into consideration perceived quality of life as well as individual perspectives on the future of rural communities. Therefore, we see development in a much wider perspective than simply economic growth or progress. Development is about enhancing individual and societal endowments and thereby increasing their capabilities and choices.

When analyzing the effect of afforestation, rural development can be seen as comprising the dimensions of contents and process, respectively. The *contents* dimension of rural development involves a range of measures, employed to impact several factors in a given area, e.g. rural economy, quality of life, landscape identity and protection of the environment. Rural development is thereby understood as a multi-dimensional process with the aim of integrating in a sustainable way different economic, socio-cultural and environmental objectives. The *process* dimension deals with the question of how the involved measures are institutionally nested, invented, implemented and executed. Commonly it distinguishes between two ideal processes, the endogenous and the exogenous. The endogenous process is based on the involvement of the rural communities in their development, frequently referred to as “bottom-up” strategies. In contrast, exogenous rural development processes are results of forces originating from outside the rural areas or “top-down strategies”.

New forests are seen as the *content* of rural development, while afforestation would represent the *process* of establishing new forests. How that process is executed significantly influences the success of any afforestation

programme. As the term rural is value loaded and afforestation is in most cases carried out on land under local tenure, we believe that integration of the local populations in the execution of policies is vital for successful results.

Afforestation

Historically the Nordic countries have been endowed with extensive native forests. However, wide-spread deforestation has taken place in some of the Nordic countries, leaving large tracts of land denuded. The passage from deforestation or forest shrinkage to afforestation has been labelled as forest transition. This process has been described for a range of countries with a large decline in forest cover, often for a relatively long period of time. At some point the trend may reverse and forest cover again increases. This turnaround point has been labelled the “forest transition point”, identifying the net woodland cover at the time of the turn when afforestation comes into the picture. The forest transition point differs between countries and can be associated with different factors, where issues like agricultural reforms, rural exodus and urbanization, wood scarcity and evolving land use policies often play an important role. Rural development is commonly identified as the key rationale when authorities and policy makers employ afforestation as a measure to improve rural conditions.

The Nordic countries provide important examples of forest transition. Afforestation has been initiated during different periods in all countries, although there are substantial regional differences. Currently, Sweden and

Figure 39. Heradsskogar afforestation programme aims to establish 35,000 ha of new forests in East Iceland. The picture shows young Siberian larch afforestation sites, planted by the local farmers for rural development. Photo: Jon Geir Petursson.

Finland are among the most heavily forested countries in Europe where forest-based industries are key economic activities. Norway also has a substantial forest cover, but regions of the country have in recent history undergone significant forest transition, especially on the west coast. There, extensive areas were afforested during the post war period, with the aim of rural development. The respective plantations are now becoming mature, ready for economic exploitation.

The two least forested Nordic countries have ongoing ambitious plans to expand woodland cover in lowland areas: Iceland from 1.5% to at least 5% and Denmark from 11% to 22%. Both countries became almost totally deprived of forests, but Denmark went through the forest transition point around 200 years ago, while Iceland did so only in the 1990s.

Although the Nordic countries have no uniform experience to share on the effects of afforestation, many interesting examples can be discussed in a comparative perspective.

Effects of afforestation on rural development

Forests and forestry are interconnected with employment and the economy in our societies. Consequently, it is the actual use of forest functions and services that has to be considered as having an effect on rural development rather than the extent of forest cover. This demands a discussion of rural forestry and how different forest functions and services can contribute to the rural community. It is also inherent that afforestation is a long term

Figure 40. Having lost almost all of its forest cover, Iceland has now halted deforestation. The results from ambitious afforestation schemes are now becoming significant in the Icelandic rural landscapes. Photo: Jon Geir Petursson.

exercise and its effects have to be evaluated in that context. Therefore the effects on rural development can be different in different periods. As an example, rural communities might appreciate the labour income generated by the establishment phase, but as the plantations mature and mechanized harvesting starts in the woodlands, controversies might arise.

It is generally assumed that forestry can increase economic vitality, social attractiveness and ecological integrity of rural areas. However, it is important to understand that afforestation can also have negative or contradictory effects. The desired effects of forestry on rural conditions are rightly assigned to four different categories: (i) community benefits, (ii) economic welfare, (iii) landscape identity and (iv) environmental/natural quality. Our focus will be on social aspects, community benefits and contributions to economic welfare. Further, we will discuss some socio-economic issues that can cause controversies in rural areas linked with afforestation.

Community benefits

The criterion of community benefits deals with the impact of forests on personal and communal values, changes in demography and gender issues. As an example, rural development could act as a measure to halt the exodus of young people from rural regions to urban areas.

Figure 41. Forests and forestry are subject to changes, and so is their role in rural development. Forestry in the Nordic countries is no longer only about economic pursuits, but also about lifestyle and environment. The Faroese pop diva Eivör Pálsdóttir performs in Hallormsstadaskógur forest in rural East Iceland. Such events can contribute significantly to rural development. Photo: Jon Geir Petursson.

Community benefits of forests are partly influenced by the objectives and management practices of the forest owners. In many rural areas, a change in values and objectives of forestry can especially be attributed to an increasing number of private forest owners. Generally, the social structure of forest ownership has altered in many regions of the Nordic countries. The former agrarian lifestyle of forest owners has partly been replaced by non-farm forms of living, and a greater number of private, non-industrial forest owners are found. Private forest owners can be divided into two main typologies with their main motivation being either production or consumption. For forest owners who have consumption as the major motivation, aspects like enjoyment, nature conservation and biodiversity become more important than the production of timber and other wood products, and they may contribute positively to the rural society. Indeed, private forest owners are increasingly interested in nature conservation and amenity values. This can have an important impact on community benefits and determine lifestyle and the well-being of the people living in rural areas.

Furthermore, although living in rural areas, many new forest owners have an increasingly urbanized lifestyle. This demands certain services of the rural community. Hence, forestry can be one of the driving forces in the development of rural communities in other fields than those directly related to forests and forestry. Therefore, the role of forestry in the development of rural areas should not only be discussed as the possibility to provide labour and income opportunities, but also in terms of life quality. People living in rural areas may perceive forests more in the context of nature conservation and landscape quality and less as an economic activity or carrier of services.

The increase in life quality due to better recreational possibilities and access to green areas is an example of how forest services not related to wood production can have a positive effect on rural communities. This can be seen in the increasing number of urban people who prefer to live in the countryside but work in cities. However, this lifestyle demands a well developed infrastructure and other social economic services, which leads us to the next category: economic welfare.

Economic welfare

The criterion of economic welfare is related to the possible impact of forests on daily existence, livelihood and the well-being of the local community. It is therefore important to consider differences in forestry and socio-economic structures between regions and countries because these

differences make it difficult to draw generally applicable conclusions on the effect of forestry on rural economic development.

A clear relationship between forest cover and regional development opportunities in many European countries has made forest resources an important factor for local employment and income in many less favoured regions. Therefore, the discussion of employment and the effect of afforestation are often directly linked to the increase in forest cover. However, forest resources as such do not create employment, although they offer possibilities for regional development. Hence, it is not necessarily the quantity of forest cover in a rural area, but the integration of forest services into the rural economy that is important.

As indicated above, the role of public forestry and private forest owners in rural economic development has changed. Foresters must now collaborate with a diverse spectrum of new citizen groups and professions involved in forest planning and management. This goes hand in hand with an increasing acceptance of multifunctional forestry. Traditional forestry has evolved into more comprehensive, integrated forest ecosystem management. The contribution of forestry to the economic vitality of rural areas is no longer restricted to primary production. For many new forest owners, traditional forestry in terms of timber production makes up only a minor part of their income. In contrast, forestry comprises diverse social values and uses, and is highly interrelated with many community socio-economic and political systems. The economic effect of afforestation is thus not only restricted to employment and the income of the rural community members but includes aspects such as infrastructure, mobility, real estate prices and other general facilities. These aspects can be difficult to assign to community benefits or economic welfare, as they play an important role in both.

Figure 42. Although there are multiple linkages between afforestation and rural development, wood production is still a key service of forests in rural Finland, contributing significantly to economic welfare. Photo: Jon Geir Petursson.

Employment is still the most important factor in the discussion of rural development. In Finland, Sweden and Norway, the forest sector makes up about 3-5% of total employment. Large-scale forest industries are important to guarantee a constant flow of income, help to maintain the infrastructure in rural areas, and keep forest owners interested in management activities. However, the adaptation of forestry to large-scale industrial needs makes the development of new opportunities difficult for small-scale owners as well as processors. In fact, employment in forestry and the large-scale forest industries has continued to decline, but employment within small- and medium-scale forest industries has become more important in many European countries. This includes also countries like Iceland, in which forestry and related industries are still young. Employment in sectors other than forestry can be enhanced as an indirect effect of afforestation. These are typically service sectors that are indirectly related to the forest industries, but also other sectors such as tourism. Many of these services will help to create stronger links between urban demand and rural supply. Finally, mobility is an important factor in making rural areas attractive for new settlers. Often, large-scale industries may help to maintain road systems and other infrastructure in the countryside. Nevertheless, once roads are built in connection with forest management activities, they will persist as a long-term effect of afforestation in areas that may earlier have been rather remote.

Socio/economic controversies

Although afforestation is often initiated to create desired outcomes in rural areas, such initiatives can cause controversy. Afforestation schemes compete for land and therefore bring constraints to traditional agricultural systems. Recently, the forest cover of many Nordic countries has expanded following agricultural reforms, namely the decrease in sheep farming in Iceland and grain farming in South Sweden. Therefore, the conversion of land to forestry can be seen as a threat to agricultural potential. The same concerns apply when abandoned agricultural land or open landscapes are afforested.

From an economic point of view, it can be claimed that creating sustainable rural forest-based jobs by afforestation programmes is relatively expensive, compared to other alternatives. On the other hand, these payments can be highly appreciated by the current landowners, creating desired economic effects in rural areas. Furthermore, forestry is a long term investment, and therefore afforestation grants are usually not perceived as

competition, as can be the case with other governmental grants and interventions. Afforestation initiatives can cause higher land prices, which is also often the intention of the schemes. However, higher land prices can cause financial problems during a generation change on the farms and may discourage new people from moving to the rural regions.

Controversies are also found around the institutional structure of afforestation schemes. If schemes are top-down enforced in the rural areas, there are few success stories. A real contribution to rural development is much more likely to be achieved if local communities are involved in all stages of the project. This is linked with the way authorities choose to implement afforestation. Economic instruments are usually preferred, awarding grants to landowners for planting trees rather than governmental acquisition of land based on legal instruments and enforcement.

Afforestation in practice

The evaluation of the effect of afforestation programmes aimed at rural development is a difficult task. Any analysis of future outcomes of afforestation is complicated by the fact that it is unavoidably a long term process that stretches beyond several generations of landowners. Future social and institutional changes can easily impact the proposed outcome and make it difficult to assess. Furthermore, as the effects on rural development are so highly context dependent, it is not possible to provide an all encompassing example. However, when comparing recent afforestation programmes in Iceland with afforestation that took place in Norway many years ago, we can see some similarities. On the west coast of Norway many similar issues prevailed 60 years ago as in rural east Iceland in the 1990s: extensive deforested areas, economic decline, low property prices, emigration and scarce off-farm employment opportunities. In both countries, governments initiated afforestation to stimulate rural development, using it as a financial instrument to channel income to the farmers. This was well received by the farmers, and extensive areas of former pasture lands have been transformed into forests. On the Norwegian west coast, the success of the tree growing exercise is hardly being debated today, as extensive, vital forest stands are now found in the region. What causes debates, however, is the issue of the actual contribution of the afforestation to the local societies. The region is still experiencing a population decline and further struggles with establishing forest-based enterprises, as a large proportion of the forest owners live outside the area and lack the incentives to engage in such rural activities.

One recent afforestation project in Iceland is the Heradsskogar project in East Iceland. Started in 1989, it aims to establish 35,000 ha of new forests, mainly with the help of local farmers. So far, the Heradsskogar project has been a success. A large proportion of the local farmers have engaged in the project, and they seem to perceive a significant level of ownership in the project. The project has already contributed significantly to local employment, and rising property prices are at least partly believed to be associated with the afforestation project. It remains to be seen how the future community will use this resource and if afforestation will contribute to rural development on a sustainable base. The experience from West Norway shows well that measuring the effect of afforestation on rural development is much more complex than being just about trees. Although the trees mature well, societal benefits may not follow.

Conclusion

Afforestation has been shown to be a possible measure for improving the development of rural areas. The Nordic countries provide good examples of different stages of forest transition and afforestation programmes and their respective effects on local communities. It should be emphasised that a positive impact of afforestation is not directly related to the increase in forest cover and the development of forest industry as other services and forest functions that follow may be equally or even more important. Nevertheless, a prediction of future outcomes is difficult as afforestation is an undertaking that takes generations, and societal and institutional conditions change over time. Presently, a change in forest ownership towards an increasing number of small-scale private owners, often with urban roots, contributes to various new forest functions that aim for consumption rather than production. Hence, afforestation is important not only for timber production and employment within the timber industry, but also for recreation, lifestyle and other socio-economic benefits. However, it was also shown that an analysis of the effect of afforestation on rural development is complicated by the difficulty of defining rurality, especially among the Nordic countries. The effects of afforestation should therefore always be considered individually for the different societies and regions.

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Effects of afforestation on the carbon cycle

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Introduction

Anthropogenic emissions of carbon dioxide (CO₂) and other greenhouse gases and their possible impacts on Earth's climate are recognised as one of the main environmental problems of today. Therefore, the Nordic countries have been strong supporters of the Kyoto protocol and in their sustainable development plan, for 2001–2004, the importance of forest management and afforestation for carbon sequestration was emphasised. Carbon sequestration is an important environmental service that can be affected by afforestation of treeless lands and management of already established forests. It is only in the past few years that this has been of high focus. For example, in an earlier synthesis of afforestation in the Nordic region by Helles and Linddal in 1996, the importance of carbon sequestration was not mentioned. However, at the international conference entitled *Effects of afforestation on ecosystems, landscape and rural development* in 2005 there were a number of papers presented that emphasised carbon sequestration as an important environmental service. Therefore it was considered important to summarise here how afforestation is linked to carbon sequestration and its role in the Nordic carbon budget.

Where and how is carbon stored in the forest?

Forests take up large amounts of CO₂ from the atmosphere through photosynthesis, which partly is stored as carbon in aboveground biomass (foliage, branches, stems and ground vegetation) and partly in soils as living and dead organic matter (Figure 43). The CO₂ is returned to the atmosphere through respiration by the living organisms that inhabit the forest or by decomposition of soil organic matter and combustion that takes place during forest fires.

Forest ecosystems contain the largest part of the carbon stored on land on Earth, both in the form of biomass and dead soil organic matter. Generally, most of the carbon stock is found in the soil, not in the tree biomass (Figure 43). The ratio between carbon in the soil and in the vegetation is often close to 2:1 in northern temperate forests and as much as 5:1 in northern boreal forests.

The turnover time of carbon in different ecosystem compartments differs greatly. In aboveground compartments it can vary from seconds to centuries (photosynthates vs. wood), whereas it may vary from hours to

Figure 43. Carbon stocks in a 55 year old downy birch stand in southern Iceland that had been established by direct seeding on eroded sand. Illustration by Thorbergur H. Jonsson.

millennia in the soil (exudates vs. dead organic matter). This is important to bear in mind when carbon sequestration is discussed. Sequestration takes place over some given time and the time step chosen will determine which compartment seems to be most important. With shorter time steps, such as decades, the change in aboveground biomass is likely to play the most important role. However, when predictions are made for centuries to millennia, changes in the soil carbon stock will always have the largest impact.

Carbon sequestration through changed forest management

Forests sequester carbon from the atmosphere at a national level if their management leads to a net increase of standing volume or soil organic matter. In Finland and Sweden the net annual CO_2 sequestration due to the increase in woody biomass during 1990–2000 amounted to 30 and 20 million tonnes $\text{CO}_{2\text{eq}}$, respectively. The annual emissions of greenhouse gases from both countries were about 70 million tonnes $\text{CO}_{2\text{eq}}$ during the same period, so the forests reduced the net emissions by 30–40%. This figure clearly shows the importance of forests and forest management on national greenhouse gas balances.

The potential to further increase the annual carbon sequestration in the existing forests relates to management options such as thinning intensity, rotation length, drainage regime, tree species, and silvicultural system (e.g. selection cutting systems vs. clear-cut systems). The present management of forests in the Nordic countries has mainly been developed to optimise the production of timber, pulp and biofuel, i.e. to maximise growth rates or stemwood production with rather short rotation lengths. Implementation of changed forest management strategies to maximise carbon stocks in existing forests could involve, for example, an increase in the rotation length. Such a change would lead to carbon sequestration at a landscape or national level during the next 100 years (the usual rotation period within the Nordic region) while the effect on the changing age structure would take place. Again, there is the problem of time scale; after the initial effect of changed age structure, the forests as a whole would be less efficient in annually storing carbon in biomass because growth rates decrease with age. This management option will therefore not lead to a final solution of the emission problem but may be useful to gain more time to direct the national energy system away from fossil fuels.

The existing forests also have important roles other than wood production; they are an important habitat for many species, they are important in maintaining water quality, they are used by people for recreational purposes and they provide employment through multiple other uses. An increase in rotation length would have an impact on these other roles of forests. Maximizing carbon storage with longer rotations may favour biodiversity and some social activities (e.g. recreation), but could have a negative influence on timber, pulp wood and bioenergy production. It is therefore important to evaluate these contrasting effects of changed forest management of the existing forests for increased carbon sequestration on timber production, biodiversity and other environmental services. There are at present currently a number of Nordic projects that are dealing with these issues.

How important is afforestation for carbon sequestration?

The importance of forests in the global carbon cycle is clearly seen in the impact of deforestation on the increasing atmospheric CO₂ concentration. Deforestation is considered responsible for a quarter of the global anthropogenic emissions of CO₂ in the past 20 years. According to FAO's statistics, the net deforestation amounted to 8.9 million ha per year between

1990 and 2000, while it was reduced to 7.3 million ha per year during 2000-2005. The main reason for reduced net global deforestation is increased forest cover in the northern hemisphere, both because of natural expansion and direct afforestation. The global afforestation amounts to 2.3 million ha each year.

Within the Nordic region forest cover is expanding. This is mostly because of land conversion from agriculture and livestock grazing, but direct afforestation is also partly responsible. The effect of afforestation since 1990 on the national greenhouse gas balance is relatively largest in Iceland, the Nordic country with the least forest cover. In a paper presented at the AFFORNORD conference it was estimated that in 2005 the carbon sequestration by afforestation amounted to ca. 3% of Iceland's 1990 CO₂ emissions, and with the plans for future afforestation this could be as much as 6–11% in 2013.

Both afforestation of treeless lands and changed forest management of existing forests enhance carbon sequestration in the Nordic countries for decades to centuries. Afforestation has more potential in Denmark and Iceland, where forest cover is low (<15%), while changed forest management of existing forests has more potential in Norway, Sweden and Finland. Both afforestation and changed forest management can play an important role in the Nordic countries' greenhouse gas balance, especially as a temporary solution while the societies change their main energy source from fossil fuels to renewable energy sources.

Gaps in our understanding of carbon sequestration by afforestation

Most of the C sequestration by afforestation is an effect of an increase of woody biomass as forest is re-established (Figures 43 and 45). As stated before, soil C stocks may exceed aboveground C stocks by 2–5 times in our forest ecosystems. How soil C stock changes after afforestation is not well understood. To better understand the long-term effect of afforestation on C sequestration we need to study the soil C dynamics.

Because of the large time step involved with soil processes, it is doubtful if forest soil C stocks have reached a steady state in the Nordic region since the ice retreated after the last glaciation ca. 10,000 years ago and the area was colonised by trees. Measurements have indeed shown that many forested areas are still accumulating soil C today. Therefore we suggest in

Figure 44. Schematic representation of possible changes in the ecosystem C stocks in a deforestation/afforestation cycle. After deforestation, carbon is lost from the system until it reaches the level supported by ground vegetation (red). After afforestation, carbon is sequestered until it reaches the amount supported by the forest stand (green). The whole line shows how C stocks could change if the system was unaffected by other dynamic external factors (fertility, forest type, nitrogen deposition, climate). The lower broken line indicates how the C stock could change if for example much organic matter was lost from the soil. The higher broken line indicates how C stocks might change if a more productive forest type was established.

Figure 44 that the long-term ecosystem C stocks are not constant but rather gradually increase if the vegetation is not disturbed. It is also important to note that most treeless landscapes that today are used for afforestation within the Nordic region were once covered by forest, but were deforested for human land use some centuries or millennia ago. When these areas were deforested the ecosystem C stock decreased because the treeless ecosystem contained less biomass aboveground, but also because of less C input to the soil (grazing, burning, soil erosion). The ecosystem C stock may not necessarily reach the same amount as it contained before the deforestation until after a number of rotations (Figure 44). How soil and litter C stocks change following afforestation is likely to be dependent on a number of factors, such as tree species and management strategies used.

There are a number of factors that can contribute to how soil and litter C stocks change following afforestation. The Norwegian and Icelandic

Figure 45. Decomposition potential in stands of different tree species, measured as tensile strengths in a cotton strip assay. Higher numbers indicate less potential. Figure from Arneberg et al. 2007.

AFFORNORD teams made a special study of how tree species used for afforestation in Iceland influenced decomposition potential in the topsoil. A clear difference in decomposition potential was found between treeless pastures and stands of different tree species (Figure 45). The tree species used for afforestation could therefore be ranked according to their increasing decomposition potential: lodgepole pine < Sitka spruce < Siberian larch < mountain birch

In future afforestation activities the different properties of tree species should be taken into consideration in order to choose the most ecologically favourable species.

Scaling up the effect of afforestation on carbon stocks

Because of the complexity and the range of time scales involved, simulation models must be used to study the effects of afforestation on ecosystem processes such as carbon sequestration. To fully understand the effect on soil processes, such models must look at ecosystem changes for at least one century or more. To simulate the effect of afforestation on carbon sequestration under Nordic conditions, the ForSAFE model was used (Figure 46). The model simulates the biogeochemical cycles of carbon, nitrogen, base cations

Figure 46. Flow chart showing how the ForSAFE model links environmental factors with changes in carbon stocks in soil, ground vegetation and trees.

and water in a forest ecosystem, with focus on tree growth, soil chemistry and soil organic matter build-up and decomposition. In this chapter, we focus mostly on the effects on the carbon stocks in the soil and aboveground.

Table 3. Description of the two contrasting afforestation sites in Sweden and Iceland used for the present study. DR = Dystric Regosol, AN = Andosol.

Site name	Lat. Long.	Mean temp. (°C)	Mean rainfall (mm)	Soil type	Forest type
Söstared, W Sweden	57.6°N 12.4°E	8.1	850	DR	<i>Initial:</i> Beech, Pine, Oak <i>Afforestation:</i> 81% Scots pine 19% Norway spruce
Hallorms- stadur E Iceland	65.1°N 14.8°W	3.4	738	AN	<i>Initial:</i> Mountain birch <i>Afforestation:</i> Siberian larch

As a case study for this report we have chosen the two most contrasting conditions we had data for within our region: Söstared, West Sweden, where afforestation took place ca. 90 years ago and Hallormsstadur, East Iceland, where afforestation took place 55 years ago (Table 3). Both places were afforested with coniferous plantations after having previously been deforested in the 14th-16th centuries and gradually converted to grazed heathlands. Land history in outline:

- Hallormsstadur:
 - o Iceland mountain birch woodland to 1650. 1650–1952 open land grazed primarily by sheep. Afforested with Siberian larch in 1952.
 - o In the model runs, we initiated during the open land period in 1800 and ran to 2100.
- Söstared
 - o Beech-Oak-Pine open forest canopy to 1650. 1650–1890 open land grazed by sheep and cattle. Afforested with Norway spruce in 1880
 - o In these runs, we initiated at 1800 with a closed forest canopy and ran to 2100.

The biogeochemistry of both sites was simulated with the ForSAFE model. From the outputs, we have chosen to highlight the dynamics of the carbon stocks in the ecosystem. This is shown in Figure 48. It can be seen that the aboveground C sequestration was larger where Norway spruce was

Figure 47. Nitrogen deposition at Söstaré and at Hallormsstadur.

used for afforestation in Sweden, largely because of the warmer climate, longer growing seasons and larger amounts of nitrogen inputs (Figure 47). But because of the higher production, the rotations in Sweden were also much shorter.

The lower aboveground C sequestration in Iceland, however, was partly compensated by a long-term increase in soil carbon, whereas at the Swedish site the amount of soil carbon was predicted to decline. In these simulations we have chosen to show the period after 1900, when the Swedish sites had increased nitrogen inputs whereas in Iceland no substantial increases occurred.

In another project closely linked to the AFFORNORD (*NECC: Nordic Centre of Excellence for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate System*) we made direct measurements of the carbon exchange in a young Siberian larch forest in eastern Iceland in 2004–2007 (Figure 49). In 2005 the plantation sequestered 727 g of CO₂ m⁻² (Figure 50). The largest proportion of this was explained by an increase in soil C. These results are in line with the modelled results for Hallormsstadur presented in Figure 48, where the soil C stock in the Siberian larch forests was expected to increase after afforestation.

At Söstaré carbon decreased first following the deforestation of broad-leaves in ca. 1650. The loss of soil C continued even after afforestation with Norway spruce (Figure 48). The reason was mainly because the conifers set root litter into the soil at shallower depths than the original broad-leaves, where decomposition was enhanced by the large nitrogen input. At Hallormsstadur there had also been a loss of soil C after deforestation around 1650. However, after afforestation in the 1950s, similar amounts

Figure 48. Comparison of the two sites modelled, Hallormsstadur in eastern Iceland and Söstared in south-western Sweden. The diagrams show forest growth as standing biomass (top), expressed as carbon, and the topsoil carbon (bottom). Symbols indicate actual measurements *in situ*.

were again being sequestered in the soil as in the 16th century. This was because there is little difference between the rooting depth of birch and larch and that the nitrogen input in Iceland is relatively small.

As discussed earlier, the rotation length is then of major importance for the amount of carbon being stored in the forests at a national level. This can also be seen at a site level in the above example. In Söstared, clearcuts come at too frequent intervals under the present practice to store much carbon on a time scale of a century or more. Therefore the effective sequestration time there was only measured in decades. At Hallormsstadur, the effective sequestration time was much longer, but still limited in time. At Hallormsstadur the stand was approaching maturation in 2100, with less net carbon being sequestered (Figure 48). However, an increase in soil C in Hallormsstadur further amplified its potential for long-term C storage.

Recently there has been much discussion on whole-tree harvesting for bioenergy within the Nordic region. At Söstared the soil C stock sequestered in the past is still declining (Figure 48). Clearly, whole tree harvesting at such a site would aggravate this decline and thus is not a good option

Figure 49. A measurement tower over a Siberian larch plantation in eastern Iceland. Micrometeorological methods can be used to study the CO_2 exchange of forest ecosystems on a second to inter-annual time scale. These can be helpful to better understand the processes that mediate changes in above- and below-ground C stocks. Photo: Brynhildur Bjarnadóttir.

from the point of view of carbon sequestration. Such management options should always consider the effect on long-term carbon sequestration. Some areas may be more suitable than others for whole-tree harvesting.

From the above example it is clear that initial conditions, land-use history, current management scheme and choice of tree species for afforestation can greatly affect the amount of carbon sequestered from the atmosphere and the duration of its storage. Selecting the most productive tree species under the most favourable growing conditions may not necessarily give the most carbon sequestration over a longer period of time. Interestingly, both the net amount and the duration of carbon sequestration were higher in the cool climate of Iceland than in the nemoral climate of West Sweden.

Figure 50. An annual carbon balance of a 13 year old Siberian larch forest in eastern Iceland. Negative numbers indicate net carbon uptake by the forest and positive numbers indicate net efflux. The annual carbon balance was $727 \text{ g CO}_2 \text{ m}^{-2}$ sequestration. Figure: Bjarnadóttir et al. 2007.

Afforestation helps in the short run to sequester carbon from the atmosphere and this may be considered an important ecosystem service. However, most of the carbon stored is not found in permanent storage. It may, however, be seen as a temporary solution while societies change their main energy sources from fossil fuels to renewable energy sources.

Conclusions

- The models show that afforestation is a possible means of counteracting increasing atmospheric CO₂ concentrations, but site conditions and choice of tree species may have a large effect, both on the amount and duration of the carbon sequestration.
- If the main goal of the afforestation is to store atmospheric carbon, then it is not necessarily the fastest growing tree species under the most favourable conditions for tree growth that has the most potential.
- The AFFORNORD study shows that integrated models are of help in interpreting past and future developments in complex systems.
- Only two sites were used in this part of the AFFORNORD study. In order to create a better overview picture, efforts should be taken to include more sites and in all the Nordic countries.
- Research on environmental services in relation to afforestation and forests is a relatively new field, where better quantification of the impacts of management is needed, especially in terms of the challenge of balancing forestry practices with their effects on carbon sequestration, economic and social objectives.

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Conclusions and recommendations

Gudmundur Halldorsson

In the AFFORNORD project, an interdisciplinary approach was taken to evaluate effects of large-scale afforestation projects. In 2005, an international conference was held at Reykholt, Iceland, on how afforestation affects ecosystems, rural development and the landscape. This led to the publication of a proceedings book in the TemaNord series (TemaNord 2007:508) including a wealth of scientific information relating to a wide range of afforestation aspects. However, the book lacked a comprehensive overview.

In the present book the active AFFORNORD participants have aimed to summarise the information presented at the conference and produced by several additional studies and workshops during 2004–2006. At the workshops we discussed different topics in greater depth, ranging from historical reviews and effects of afforestation on wood supply, to effects on public health and geodiversity. All of these topics are important when the over-all effects of afforestation are evaluated. The hope was that, by making such an interdisciplinary study, we could give a balanced evaluation of how afforestation can be optimized in relation to various benefits, disadvantages and challenges.

What can we learn from working together?

The Nordic region is homogeneous in culture, lifestyle and political system. This is reflected, for example, in the establishment of the Nordic Council of Ministers. However, the natural environment differs greatly within the Nordic region. In prehistoric times the Nordic countries had more forest cover than today, but the dominant land-use led to large scale deforestation in some regions, while others have kept their forest cover more intact.

The present forest cover ranges from 0.1% of the total land area in the Faroe Islands to 69% in Finland. Generally speaking, the southern and western part of the region initially experienced most severe deforestation, subsequently followed by large-scale afforestation efforts during the past 150 years. Large-scale afforestations were initiated already in the 19th century in Denmark, in the 1930s in West Norway and by the end of the 1980s in Iceland.

The considerable time-span gives opportunities to use knowledge and experience from regions already well into the afforestation process, for the benefit of other regions that are in their primary phase. In the beginning of the afforestation phase the primary goals were production of raw materials for the forest industry. However, during this long period the main goals have shifted somewhat, from wood production to multiple-use forestry.

Critical findings on the benefits of afforestation

Wood production

- Timber is an environmentally friendly and versatile raw material. It has a very small carbon "footprint" and can be used as a renewable energy source. Climate change and sustainability issues are likely to make these characteristics increasingly valued in the coming decades.
- In some areas there is a potential for increasing the yield of timber by changing tree species.
- Timber is the primary source of direct revenue for many woodland owners and their main motivation for multipurpose forest management.
- International competition will maintain pressure on timber prices for the foreseeable future.
- A crucial question is how to influence rural business activities in a constructive way to ensure a more efficient outcome of afforestation programmes.

Biodiversity

- Fungi and soil invertebrates respond to afforestation with an increase in species richness.
- In Iceland the density of breeding birds and the density of soil fauna are significantly higher in native birch forests as well as exotic conifer plantations compared to heathlands.

Landscape and geo-diversity

- Afforestation can be used to protect specific landscapes by halting or preventing erosion.

Recreation and public health

- Nature provides us with essential resources for our survival and which are of critical importance for human health and well-being.
- Many studies have found a positive relationship between human experiences of nature and our social, mental and physical health.
- People seem to react differently, and most often, positively, to the natural environment compared to urban sites.

- Nature preferences seem to be very similar within the Scandinavian countries: people like landscape variation that includes characteristics of the genuine natural environment.
- A forest is an ideal alternative for offering varied nature experiences and for reloading ones mental and physical strength since such an environment only requires spontaneous concentration.

Rural development

- Afforestation can bring much needed economic activity and employment to rural areas.
- The Nordic countries provide good examples of different stages of forest transition and afforestation programmes, and on their effects on local communities.
- It can take generations, and some societal and institutional change, to fully realize the effects of afforestation on rural development.
- A change in forest ownership towards an increasing number of small-scale private owners contributes to various new forest management strategies. Such services and forest functions may contribute equally or even more importantly to rural development than direct effects of timber industry.
- An analysis is complicated by the difficulty of defining the rural context, especially across the Nordic countries. The effects of afforestation should therefore always be considered individually for the different societies and regions.

Carbon sequestration

- Climate change is one of the most serious threats facing the world today. The main driving factor is believed to be the increasing concentrations of CO₂ and other greenhouse gases in the atmosphere.
- Afforestation makes a net contribution to reducing atmospheric CO₂ by carbon storage in growing biomass, vegetation and soils.
- Carefully selecting sites and species for afforestation and changing forest management practices can increase the net amount of carbon taken up and stored.
- If the main goal of the afforestation is to store atmospheric carbon, then it is not necessarily the fastest growing tree species under the most favourable conditions for tree growth that has the highest potential.

- A further contribution is made when wood fuel substitutes for fossil fuel, and timber and wood products substitute for more energy intensive materials such as concrete or steel.
- Research on environmental services of afforestation and forests is a relatively new field, where better quantification of the impacts of management is needed, especially in terms of the challenge of balancing forestry practices with their effects on carbon sequestration and with economic, conservation and social objectives.

Critical findings on the challenges of afforestation

Biodiversity

- The number of species of vascular plants is negatively affected by afforestation. Following afforestation on open heathland, shade tolerant plant groups replace the original plant communities.
- Afforestation causes significant changes in species composition for all functional groups, even if the total species richness is not much affected. It is therefore very important to include strategies for conservation of biodiversity in forest planning and management to preserve specific habitat types or endangered species.
- The negative effect of large-scale afforestation in Iceland on open country birds, where Iceland has by far the largest breeding populations, is of significant concern.
- Countries may not always be comparable when it comes to effects of afforestation. In Iceland similar collembola species and species dominance are found in birch and exotic conifer forests, whereas in Norway the birch forests differ strongly in collembola population from coniferous forests in species composition as well as in dominance.

Landscape and geo-diversity

- Afforestation may cause loss of view and landform visibility, since forests often cover vast areas and geological formations. It may also cause physical damage to small-scale landforms and stabilize dynamic landforms, which may be of specific value, such as sand dunes.

- There should not be any planting in gullies, craters, lava fields or important geo-sites. Geo-diversity should also be taken into account in planning and nature management at all levels.
- It is important to use landscape analysis and plan open spaces and maintain open views in areas for afforestation.
- Afforestation can cause irreversible changes to cultural heritage and can damage archaeological sites. This should be of special concern when afforestation is planned.

Rural development

- Afforestation programs have not always managed to halt population decline and it has been difficult to establish forest-based enterprises, as a large proportion of the forest owners live outside the area.
- Afforestation programmes may compete with other land uses.

The discussion on the effects of afforestation in this book has highlighted a range of changes caused by afforestation and the difficulties in making a general conclusion considering those changes. Even within specific research fields, the effects of afforestation vary. However, the AFFORNORD project has highlighted similarities between some research fields.

Forest planning and management are of critical importance for biodiversity, landscape dynamics, human health and rural development. In the planning phase the purpose of afforestation must be clear in order to properly select tree species and design the future forest landscape. At this point it must be realised that there are certain conflicts between forest mainly for wood production and forests intended mainly for other uses. Stand density is of critical importance and the use of sparser coniferous stands, selection harvesting, mixed forests or broadleaved forests can sometimes better fulfil different objectives. This is for example the case for the reduction in loss of biodiversity and for rehabilitation of land for recreation or grazing.

It is also imperative to consider landscape, geodiversity and the cultural heritage that are characteristic of each site when planning afforestation. In afforestation planning, care must be taken to preserve areas and sites that contain nature types, species or cultural heritage of special importance or value, either locally, regionally or globally.

The effects of afforestation on biodiversity, discussed in this book, are mainly on a small spatial scale. However, the effects of biodiversity on the landscape scale are normally believed to be smaller, due to the fact that af-

forestation is usually carried out only in some parts of the total landscape. Thus, even if the species are affected more or less severely within the planted stands, there may well be neighbouring areas that continue to be suitable for survival of the living species. However, afforestation may also affect biodiversity on the landscape scale through other mechanisms and small stands can have significant effects when landscape issues are considered.

Another important point to emerge during the AFFORNORD work was that if tree planting occurs where forest use and forest industry are no longer part of the culture, it is important to gradually educate the local population on how to manage and utilize the new resource.

Proper forest management is vital to maintain the original plan of forest use or to adapt to new or changing goals. For example, heavy thinning of plantation forests can make them more attractive or suitable habitats for humans as well as other organisms. In this context, a variation in thinning practices, across age classes and forest types as well as spatially throughout the forest may also contribute positively to a range of multiple-use objectives. Nevertheless, timber is still the primary source of direct revenue for most woodland owners and their main motivation for multipurpose forest management. If other ecosystem services, such as carbon sequestration, would create an income for the forest owners this could possibly enhance their interest in alternative management practices.

The way forward

There is no doubt that afforestation affects ecosystems, landscapes and rural development in several ways, positively as well as negatively. No land-use, whether it be afforestation or other uses, meets all environmental goals simultaneously. Some negative impacts are inevitable, even if the most conscientious management is employed. Generally, a trade-off must be made between the desire for a more-or-less pristine environment and the need for a working and operational landscape for the benefit of society at large.

It is also important to note that some will always consider afforestation negative and harmful, even in treeless landscapes. We believe that the best way forward is to strengthen the planning process of afforestation, so as to take multiple effects into account and simultaneously to put strong emphasis on extension work to stimulate the use of the new emerging renewable resource for the direct benefit of local communities.

Dansk sammendrag

AFFORNORD er et samarbejds- og forskningsprojekt under Nordisk Ministerråd. Projektet har til formål at give en sammenfattende vurdering af den indflydelse, som skovrejsning har på økosystemer, landskab og regionaludvikling. I denne bog diskuterer vi indflydelsen af skovrejsning i forhold til vedproduktion, biodiversitet, landskab, offentlig sundhed, regionaludvikling og kulstofbinding.

De vigtigste konklusioner fra projektet er følgende:

Vedproduktion:

- Vedproduktionen afhænger først og fremmest af træarten i forhold til klima og jordbund. Træartsvalget er derfor meget afgørende.
- Tømmer og brænde er den primære kilde til direkte indkomst for mange skovejere og deres primære motivation for flersidig skovdrift.
- International konkurrence vil formodentlig fastholde lave priser på traditionella vedprodukter længe endnu. Forøget brug af vedprodukter til opvarmning og biobrænde for at modvirke væksthuseffekten kan dog muligvis forhøje priserne i fremtiden.
- Der er en direkte sammenhæng mellem det regionale erhvervslivs udvikling og det privat- og samfundsøkonomiske potentiale ved skovrejsning.

Biodiversitet:

- Skovrejsning medfører øget artsdiversitet for svampe og jordinvertibrater, hvilket delvis (eller helt) opvejer tab af artsrigdom for planter og fugle.

- Skovrejsning kan give anledning til en markant ændring i artssammensætning for alle funktionelle grupper af organismer, selvom artsrigdommen samlet set kan være uændret.
- Skovrejsning på områder eller habitater som er af særlig stor betydning for bestemte arter, for eksempel visse fuglearter, giver anledning til særlig bekymring.
- Skovrejsningens indflydelse på biodiversiteten kan variere fra land til land og fra region til region.

Landskab og offentlig sundhed:

- Skovrejsning kan resultere i tab af udsigt over landskabet og dermed ændre indtryk af landskabets form og opbygning.
- Nye skove bør designses således, at de passer til de øvrige landskabselementer og landskabets karakter, og således at skarpe, lige kanter undgås. Det er også vigtigt at bevare åbne partier i skoven med udsigt over landskabet.
- Skovrejsning kan medføre uoprettelige skader på kulturminder. Dette bør så vidt muligt undgås ved omhyggelig planlægning og udførelse af nye tilplantninger.
- Skovrejsning kan være et effektivt værn mod erosion og derved medvirke til at bevare visse landskabsformer og fysiske installationer i landskabet.
- Der findes en positiv sammenhæng mellem menneskers naturoplevelser og deres sundhedstilstand. Mennesker reagerer anderledes, i de fleste tilfælde positivt, over for naturlige omgivelser sammenlignet med storbymiljøer. En skov er et ideelt sted for en varieret naturoplevelse og for at genopfriske ens mentale og fysiske styrke.

Regionaludvikling:

- Skovrejsning kan bidrage positivt til landområdets økonomiske udvikling og beskæftigelse, men makter ikke altid at stoppe en negativ populationsudvikling.
- Det kan tage meget lang tid før skovrejsningens indflydelse på den regionale udvikling er fuldt realiseret.
- En forøgelse af antallet af små skovejere bidrager med nye skovfunktioner som sigter mere mod forbrug end vedproduktion.

- Effekten af skovrejsning er forskellig for forskellige Nordiska samfund og regioner.
- Skovrejsning kan konkurrere med andre muligheder for anvendelse af det åbne land.

Kulstofbinding:

- Skovrejsning bevirker en netto reduktion i atmosfærens indhold af kulstofteilte ved at lagre kulstof i biomasse og jord.
- Lokalitetsoptimalt valg af træart og skovdriftsmetoder kan medvirke til en nettoforøgelse af kulstofoptagelsen og kulstoflagringen.
- Det er ikke nødvendigvis de hurtigst voksende træarter, som på en given lokalitet har det højeste potentiale for kulstofbinding.

Skovrejsning har uden tvivl flere effekter på økosystemer, landskab og regionaludvikling, positive som negative. Ingen anvendelse af det åbne land, uanset om det er til skovdyrkning eller andre formål, kan imødekomme alle miljømål på én gang. Nogle af de negative effekter er uundgåelige, uanset om man bestræber sig på en miljørigtig skovdyrkning. Skovrejsning indebærer nødvendigvis en balancegang mellem det ønskelige, mere eller mindre oprindelige miljø og behovet for et arbejdsorienteret og operationelt landskab til gavn og glæde for samfundet som helhed.

Appendix 1: Participants in the AFFORNORD project

Icelandic Forest Research, Mogilsa

Gudmundur Halldorsson, project leader
Edda Sigurdis Oddsdottir, project secretary
Brynhildur Bjarnadottir
Olafur Eggertsson
Karl Gunnarsson
Brynja Hrafnkelsdottir
Jon Geir Petursson

Agricultural University of Iceland

Bjarni E. Gudleifsson
Eva Ritter
Bjarni Didrik Sigurdsson
Audur Sveinsdottir

Entomological Research, Tjöme, Norway

Arne Fjellberg

Lund University, Sweden – Department of Chemical Engineering

Salim Belyazid
Hördur Haraldsson
Harald Sverdrup

Møre Research, Volda, Norway

Johan Barstad
Paul Mitchell-Banks

The Forestry Service of the Faroe Islands

Janus Hansen
Trondur Leivsson

The Icelandic Institute of Natural History

Asrun Elmarsdottir
Gudridur Gyda Eyjolfssdottir
Maria Ingimarsdottir
Borghthor Magnusson
Olafur K. Nielsen
Erling Olafsson

The Norwegian Forest and Landscape Institute

Per Holm Nygaard
Odd Stabbetorp
Bernt-Håvard Øyen

Swedish University of Agricultural Sciences

Anna Maria Palsdottir

Torshavn kommune, the Faroe Islands

Tori i Höyvik

University of Copenhagen

Jørgen Eilenberg
Susanne Harding
Flemming Rune
Jens Peter Skovsgaard
Frank Søndergaard Jensen

Appendix 2: Projects linked to AFFORNORD

Denmark

Pre-commercial thinning of oak 2002-2005

Project leader:

Jens Peter Skovsgaard

Participating institutes:

Forest & Landscape, KU, Denmark

Bregentved Estate

Aarhus City

Haderslev National Forest

Supported by:

The Danish Forest and Nature Agency's
Fund for experimental silviculture
2002-04 and 2005-07

SNS-Carbon 2003-2006

Project leader:

Karin Hansen

Participating institutes:

Forest & Landscape, KU, Denmark

IFRE-EAU, Estonia

METLA, Finland

Icelandic Forest Research,

Iceland

SILAVA, Latvia

LFRI, Lithuania

Skogforsk, Norway

UMB, Norway

Skogforsk, Sweden

SLU, Sweden

Supported by:

Samnordisk Skogforskning (SNS)

Centre of Advanced Forest Research on Environmental Services CAR-ES 2004-2009;

<http://www.nordicforestry-cares.org/>

Project leader:

Per Gundersen

Participating institutes:

Forest & Landscape, KU, Denmark

Skogforsk, Sweden

Icelandic Forest Research, Iceland

Agricultural University of Iceland

Skogforsk, Norway

METLA, Finland

Lithuanian Forest Research Institute,
Lithuania

Silava, Latvia

SLU, Sweden

Supported by:

Samnordisk Skogforskning (SNS)

Nature-oriented afforestation 2003

Project leader:

Jens Peter Skovsgaard

Participating institutes:

Forest and Landscape Denmark

Danish Forestry Extension, District

North-East Jutland

Supported by:

The Danish Forest and Nature Agency's
Fund for experimental silviculture 2003-07

Analyses of silvicultural afforestation experiments on former heathland 2004

Project leader:

Jens Peter Skovsgaard

Participating institutes:

Forest & Landscape, KU, Denmark

Supported by:

Jutlandish Land Reclamation

Fund 2004-06

Iceland

ICEWOODS 2003-2006

Project leader:

Bjarni Didrik Sigurdsson

Participating institutes:

Agricultural University of Iceland

Icelandic Forest Research

The Icelandic Institute of Natural History

Supported by:

Rannís – Icelandic Research Council

Succession of ectomycorrhiza and nutrient status in forests 2005-2008

Project leader:

Gudmundur Halldorsson

Participating institutes:

Icelandic Forest Research

Agricultural University of Iceland

Supported by:

Rannís – Icelandic Research Council

FORSTREAM 2007-2009

www.forstreams.is

Project leader:

Bjarni Didrik Sigurdsson

Participating institutes:

Agricultural University of Iceland

Hekluskojar

Icelandic Food Research - MATÍS

Icelandic Forest Research

Soil Conservation Service of Iceland

Institute of Freshwater Fisheries

in Iceland

Queen Mary, University of London

The Macaulay Institute, Aberdeen

University of Iceland

Supported by:

Environmental and Energy

Research Fund

Centre for Advanced Forest

Research on Ecosystem Services

(CAR-ES)

Effects of forest fertilization and precommercial thinning on carbon sequestration in a Kyoto forest 2003-2005

Project leader:

Bjarni Didrik Sigurdsson

Participating institutes:

Icelandic Forest Research

Agricultural University of Iceland

University of Iceland

SLU, Sweden

Supported by:

Rannís – Icelandic Research Council

Norway

Ecological effects of non-native tree species

Project leader:

Per Holm Nygaard

Participating institutes:

Norwegian Forest and Landscape Institute

Norwegian Institute for Nature Research (NINA)

Supported by:

Ministry of Agriculture and Food

Non-native silvicultural tree species in coastal areas: Effects on landscape and biodiversity

Project leader:

Odd E. Stabbetorp

Participating institutes:

Norwegian Institute for Nature Research (NINA)

Norwegian Forest and Landscape Institute

Supported by:

Ministry of Agriculture and Food
The Research Council of Norway

Sweden

ASTA Phase I 1999-2003, Phase II 2004-2007

Project leader:

Per Inge Grennfelt

Participating institutions:

Swedish Environmental Institute,
Göteborg
Institute of Ecology and Genetics, Umeå
University
ITM, Stockholm University
Political Science, Göteborg University

Supported by

MISTRA

SUFOR Phase I 1996-1999, Phase II 2000-2004.

Project leaders

Bengt Nihlgård 1999-2003
Ola Salnäs

Participating institutions:

Chemical Engineering, Lund University
South Swedish Forestry, Swedish
University of Agriculture, Alnarp
Swedish School of Forestry, Swedish
University of Agriculture, Umeå

Supported by

MISTRA

CLIMAITE 2004-2008

Project leader:

Claus Beier,

Participating institutions:

Copenhagen University
Risø National Laboratory, Denmark
Lund University

Supported by

VELUX

NECC: Nordic Centre of Excellence 2003-2008; www.necc.nu

Project leader:

Anders Lindroth

Participating institutes:

Dept. of Physical Geography and
Ecosystems Analysis, Lund University
Dept. of Production Ecology, SLU,
Uppsala
Dept. of Forest Ecology and
Management, SLU, Umeå
Dept. of Ecology and Environmental
Science, Umeå University
Dept. of Botany, Göteborg University
Dept. of Physical Sciences, University
of Helsinki
Lammi Biological Station, University
of Helsinki
Dept of Forest Ecology, University
of Helsinki
Dept of Environmental Sciences,
University of Kuopio
Finish Meteorological Institute
Icelandic Forest Research, Mógilsa
Agricultural University of Iceland
Risø National Laboratory, Denmark
Inst. of Geography, University of
Copenhagen

Supported by:

NOS-N and NordForsk

Environmental effects of shorter forest rotation in a landscape perspective

Project leader:

Jan-Erik Weslien

Participating institutes:

Skogforsk, Sweden
Agricultural University of Iceland
METLA, Finland

Supported by:

Samnordisk Skogforskning (SNS)

**The Swiss Air Pollution and Critical
loads programme: 2000-2008**

Project leader

Beat Ackermann

Participating institutions:

BUWAL, Bern, Schweiz Institut für
Angewandte Pflanzenökologie Basel,
Schweiz

EKG, Bern, Schweiz

Ökologie und Umweltwissenschaften,

ETH-Z, Zürich, Schweiz

Lund University

Appendix 3: Species names

English names	Latin names	Danske navne	Íslensk heiti
Alder	<i>Alnus glutinosa</i>	Rødel	Rauðölur
Alpine bistort	<i>Polygonum viviparum</i>	Topspirende pileurt	Kornsúra
Ash	<i>Fraxinus excelsior</i>	Ask	Evrópuaskur
Beech	<i>Fagus</i>	Bøg	Beyki
Birch	<i>Betula</i>	Birk	Birki
Black cottonwood	<i>Populus balsamifera</i>	Poppel	Alaskaösp
Bog bilberry	<i>Vaccinium uliginosum</i>	Mosebølle	Bláberjalyng
Downy birch	<i>Betula pubescens</i>	Birk	Birki
Dunlin	<i>Calidris alpina</i>	Almindelig ryle	Lóuþræll
Elm	<i>Ulmus</i>	Elm	Álmur
European larch	<i>Larix decidua</i>	Lærk	Lerki
Fir	<i>Abies</i>	Ædelgran	Þinur
Godwit	<i>Limosa limosa</i>	Stor kobber-sneppe	Jaðraka
Goldcrest	<i>Regulus regulus</i>	Fuglekonge	Glókollur
Golden plover	<i>Pluvialis apricaria</i>	Hjejle	Heiðlóa
Grey alder	<i>Alnus incana</i>	Gråel	Gráölur
Hazel	<i>Corylus avellana</i>	Hassel	Hesliviður
Heath wood-rush	<i>Luzula multiflora</i>	Mangeblomstret frytle	Vallhæra
Japanese larch	<i>Larix kaempferi</i>	Japansk lærk	Japanslerki
Juniper	<i>Juniperus communis</i>	Enebær	Einir
Lady's bedstraw	<i>Galium verum</i>	Gul snerre	Gulmaðra
Larch	<i>Larix</i>	Lærk	Lerki
Lime	<i>Tilia</i>	Lind	Lind
Lodgepole pine	<i>Pinus contorta</i>	Murrays fyr	Stafafura

English names	Latin names	Danske navne	Íslensk heiti
Lutzi spruce	<i>Picea x lutzii</i>	Lutzi gran	Sitkabastarður
Meadow pipit	<i>Anthus pratensis</i>	Engpiber	Þúfutittlingur
Moss campion	<i>Silene acaulis</i>	Tue-limurt	Lambagras
Northern bed-straw	<i>Galium boreale</i>	Trenervet snerre	Krossmaðra
Norway spruce	<i>Picea abies</i>	Rødgran	Rauðgreni
Oak	<i>Quercus</i>	Eg	Eik
Redpoll	<i>Carduelis carduelis</i>	Gråsiken	Auðnutittlingur
Redshank	<i>Tringa totanus</i>	Rødben	Stelkur
Redwing	<i>Turdus iliacus</i>	Røddrossel	Skógarþröstur
Rock ptarmigan	<i>Lagopus muta</i>	Rype	Rjúpa
Rowan	<i>Sorbus aucuparia</i>	Rønnebærtræ	Reyniviður
Scots pine	<i>Pinus sylvestris</i>	Skovfyr	Skógarfura
Shady horsetail	<i>Equisetum pratense</i>	Lund-padderok	Vallelfting
Sheathed sedge	<i>Carex vaginata</i>	Fåkapslet-star	Slíðrastör
Siberian larch	<i>Larix sibirica</i>	Sibirisk lærk	Síberíulerki
Sitka spruce	<i>Picea sitchensis</i>	Sitkagran	Sitkagreni
Snipe	<i>Gallinago gallinago</i>	Bekkasin	Hrossagaukur
Stone bramble	<i>Rubus saxatilis</i>	Fruebær	Hrútabær
Viviparous fescue	<i>Festuca vivipara</i>	Topspirende svingel	Blávingull
Wavy hair-grass	<i>Deschampsia flexuosa</i>	Bølget bunke	Bugðupuntur
Whimbrel	<i>Numenius phaeopus</i>	Lille regnspove	Fjöruspói
Wild thyme	<i>Thymus praecox</i>	Skotsk timian	Blóðberg
Wood crane's bill	<i>Geranium sylvaticum</i>	Skov-storkenæb	Blágresi
Wren	<i>Troglodytes troglodytes</i>	Gærdesmutte	Músarrindill
Fungi	<i>Paecilomyces farinosus</i>		
Fungi	<i>Chalciporus piperatusa</i>		
Fungi	<i>Hebeloma</i>		
Collembola	<i>Parisotoma notabilis</i>		
Collembola	<i>Lepidocyrtus lignorum</i>		
Collembola	<i>Protaphorura pseudovanderdrifti</i>		