An examination of the need for Afforestation in Northern Ireland.

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Effects of afforestation on ecosystems, landscape and rural development

Proceedings of the AFFORNORD conference, Reykholt, Iceland, June 18–22, 2005

Eds. Gudmundur Halldorsson, Edda Sigurdis Oddsdottir and Olafur Eggertsson

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Content

Preface

Gudmundur Halldórsson

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Forests and forest exploitation have played a major role in the economy and ecology of the Nordic countries. This important resource has, however, been heavily exploited throughout the centuries, with the consequence that forests were almost eradicated in three of the Nordic countries; Denmark, Iceland and the Faroe Islands. All three countries had more or less continuous forest cover before human exploitation eradicated it; mixed broadleaved forest in Denmark (Helles & Linddal 1996), birch woods in lowland Iceland (Sigurdsson *et al.* 2006) and to some extent in the Faroe Islands (Jóhansen 1989, Hannon 2001). By the beginning of the 19^{th} century the forest only covered 2–3% of the total land area in Denmark (Helles & Linddal 1996), and in Iceland the forest coverage was below 1% in the beginning of the 20^{th} century (*cf.* Sigurdsson *et al.* 2006). The forest totally disappeared from the Faroe Islands ca 1000 years ago (Jóhansen 1989, Hannon 2001). Similar large-scale forest clearance also took place in certain regions of Fennoscandinavia, such as S- and W-Sweden and W-Norway (Öyen 2006).

All these countries are or have tried to re-establish the forest resource. Western Sweden and Norway were much afforestated in historical times, with large increases in their regional forest areas (Öyen 2006). There has also been an intensive afforestation for the last two centuries in Denmark, raising the forests cover to 11% of the total land area (National Forest and Nature Agency 2000). Afforestation projects have been launched in Iceland and trees have been reintroduced to the Faroe Islands (Sigurdsson *et al.* 2006, Leivsson 1989). In these three last countries the aim is to increase forest and other woodland cover (e.g. shelterbelts and amenity plantings) significantly in the near future. In Denmark the aim is to double the forest cover and in Iceland to triple it during next 40 years (National Forest and Nature Agency 2000, Sigurdsson *et al.* 2006). By afforestation these countries want to positively influence the rural development in each country, create or improve natural resources, restore lost ecosystems, improve living conditions for humans as well as to mitigate constantly increasing atmospheric carbon dioxide concentration (Baardsen *et al*. 2005, Öyen 2006).

As the development of afforestation is at very different stages in different regions of the Nordic countries it is important to study the local and regional impact all across the Nordic scene. Information at the landscape level is particularly important, providing a basis for objective monitoring of environment and biodiversity change and its causes. Especially regarding the challenges posed on the life of forest owners from the modern society, there is a need to study the relations between the forest segment and the rest of society, on the local, regional, national and international scale and to develop adequate strategies for sustainable utilization of this resource. It is important in such a study to focus on the multiple uses of and benefits from forests and how afforestation can contribute into other sectors, such as tourism, recreation, public welfare and rural development. This calls for a multidisciplinary study where scientists from different disciplines and different countries work together to analyse the whole scene.

In the AFFORNORD project we are studying the influence of afforestation on the ecosystem, rural development and landscape; comparing regions, which are at different stages in forest development, and comparing afforestation with exotic trees with afforestation with indigenous trees. We are comparing regions where afforestation has a long history (W-Sweden, Denmark, West Norway) with regions where afforestation started more recently (Iceland, the Faroe Islands). We are comparing afforestation with exotic tree species with afforestation with indigenous tree species. Furthermore, we are comparing afforestation in regions where the forest ecosystem was totally eradicated (the Faroe Islands) to regions with low coverage forests and simple forest ecosystems remained (Iceland) to regions with moderately high forest coverage with more complicated forest ecosystems (West Sweden, West Norway, Denmark).

On June 18th–22nd the AFFORNORD scientific committee organised a conference on the effects of afforestation on ecosystems, landscape and rural development in Reykholt, Iceland. The conference included different topics; stretching from biology to sociology, from insect communities to human communities, and from microhabitats to landscapes. The conference consisted of common plenary sessions, opened by invited speakers, as well as sessions split between biodiversity and modelling on one hand and rural development and landscape on the other hand. The conference was sponsored by different organizations under the Nordic Council of Ministers. These were; NEJS – Nordisk Embedsmandskomite for Jord- og Skovbrugsspørgsmål, MJS – Styrgruppen för Miljøstrategier for Jord- og Skovbrug, BU – Det Nordiske Miljøhandlingsprogram and SNS – Samnordisk Skovforskning. The conference was also sponsored by the Agricultural Ministry of Iceland, the Icelandic Forest Service, the Icelandic Forest Research, the Icelandic Institute of Natural History and the Agricultural University of Iceland. I am very grateful for the contribution of all these organisations and want to express my sincere thanks.

I am very grateful to all those people that made this conference possible and contributed to the proceedings from the conference. I especially want to thank the invited speakers; Bill Freedman, Mick Marquiss, Simon

Bell, Aine Ni Dhubhain and Harald Sverdrup. I also want to thank the other members of the scientific committee, Susanne Harding, Jens Peter Skovsgård, Odd Egil Stabbetorp, Johan Barstad, Harald Sverdrup and Tróndur Leivsson for their effort that made the conference possible. I would also like to thank the organizing committee, Edda S. Oddsdóttir, Audur Sveinsdóttir, Ásrún Elmarsdóttir, Bjarni D. Sigurdsson, Borgthór Magnússon and Karl S. Gunnarsson. As the scientific secretary of the project, Edda took care of correspondences with all the people wanting to contribute to the conference, compiled the book of abstracts and did all the other vital things needed for making a conference possible. For this I would like to thank her especially. Ragnheidur Stefánsdóttir from Iceland Incentives Inc. took care of practical arrangements for which the organizing committee is very grateful. Many other people, whose names are not included here, contributed and I would also like to thank them for their contribution.

The AFFORNORD conference on the effects of afforestation on ecosystems, landscape and rural development was a very important step in the process of gaining an overview over the multi-scale effects of afforestation in the Nordic countries. Such an overview will be the scope of the final report from the AFFORNORD project.

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1. Keynote papers

1.1 Benefits of Afforestation

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Abstract

Afforestation is the managed restoration of a forested ecosystem on land that is presently in a non-forested condition. Afforestation can result in important economic and ecological benefits, including: (1) the development of an enhanced resource of tree biomass, which is a potentially renewable source of energy and material; (2) enhanced ecological functioning, such as clean-water and clean-air services and increased carbon storage; and (3) the provision of additional habitat for biodiversity. The implications of an afforestation project for resource and ecological values depend on several interacting factors, including: (1) the condition of the land to be rehabilitated, particularly the degree to which it is ecologically degraded; (2) the kind of afforestation project being contemplated — is the intent to develop a high-yield plantation of a particular tree species, possibly a non-indigenous one, or is it to reconstruct a facsimile of a natural forest appropriate to local biogeography and site conditions?; and (3) the rarity or degree of conservation risk of the forest type being developed, and of the species it is expected to support. These factors will be discussed and illustrated using case material from several projects in Canada.

Deforestation

Deforestation refers to the long-term conversion of a forested site or landscape to a non-forested condition. It is one of the most important kinds of environmental damage that humans have caused — only about 54 percent of the world's original forested area is still covered by tree-dominated ecosystems (World Resources Institute, 2005). The most important cause of deforestation has been agricultural development, but urbanization, fuelwood and timber harvesting, and industrial activities are also important in some regions.

Of course, not all countries have been similarly afflicted by deforestation. Table 1 shows data for a range of countries, but with particular attention to northwestern Europe and North America. Countries can be aggregated into three broad groups:

- *Those which have suffered the loss of virtually all of their original forest cover*, as is the case of Uruguay, Iceland, Denmark, Ireland, and the Netherlands (these are listed in order of decreasing intensity of deforestation; note that although WRI estimates that only 0.1% of the forest cover of Iceland survives, other estimates are closer to 1%)
  Others which are relatively well-forested but have lost almost all of their frontier forest, a term that refers to large self-organizing tracts with high levels of ecological integrity (and so capable of accommodating natural disturbance dynamics and of supporting the expected communities of indigenous species). These countries include France, India, China, Germany, Japan, Finland, Sweden, and Norway.
- *A final group that still retains most of the original forest cover,* including much of their frontier forest. These countries include Brazil, the Russian Federation, and Canada.

Table 1. Deforestation, frontier forest, and modern forested area for selected countries. Forest area is for 2002; other data are for 1996 (WRI, 2005).

	% original forest surviving	frontier forest as % of original	Total forest area x 10^6 ha
Uruguay	<0.1	0.0	1.29
Iceland	<0.1	0.0	0.031
Denmark	0.8	0.0	0.46
Ireland	3.6	0.0	0.66
Netherlands	4.8	0.0	0.38
United Kingdom	6.0	0.0	2.79
Bangladesh	7.9	3.8	1.33
France	16.5	0.0	15.3
India	20.5	1.3	64.1
China	21.6	1.8	163
Germany	26.3	0.0	10.7
Japan	58.2	0.0	24.1
United States	60.2	6.3	226
Brazil	66.4	42.2	544
Russian Fed’n	68.7	29.3	851
Finland	82.3	1.1	21.9
Sweden	86.0	2.9	27.1
Norway	90.4	0.0	8.9
Canada	91.2	56.5	245
Global	53.4	21.7	3869

Forests in Canada

I would now like to highlight conditions in Canada, because it is one of the world's great forested countries, and also where my personal experience is deepest. Canada's cover of forest and more open woodland is about 402 x 10^6 ha (Canadian Council of Forest Ministers, 2005). This is the 3rd-largest forest estate in the world, after Russia and Brazil. About 310 x 10^6 ha of Canadian forest has a relatively closed canopy, and 47% of that is considered "economically accessible" for commercial purposes. About 63% of the forest is boreal in character, and the remaining 37% comprises various kinds of temperate forests. Overall, 40% of Canada is presently forested, an area that represents about 91% of the original forest cover, including 57% of the original frontier forest. During the past several decades, the rate of net deforestation has hovered close to 0.0% annually.

An immense forest-based economy is supported by the immense forested estate of Canada. In 2004, the exports of forestry products totalled $39.2 billion dollars (Canadian), contributing $36 B to the sectoral balance of trade (only $3.2B of products were imported; CCFM, 2005). The total forestry-related Gross Domestic Product was $71B, or about 7% of the national GDP. Of course, this massive industrial activity is necessarily supported by the harvesting of tree biomass from extensive areas of forest — about 1 x 10^6 ha of mature forest are harvested annually, 91% of that by clear-cutting. It is important to understand, however, that little of the timber harvesting in Canada results in deforestation. This is because almost all harvested stands are reforested by either natural regeneration or by the facilitated recovery (usually by planting) of another forest. About 57% of harvested sites in Canada reforest naturally and the other 43% is replanted with tree seedlings — at the national level, the area of deforestation is too small to report.

It must also be acknowledged that Canada has a huge forest-based economy outside of forestry. It is not well quantified, but is surely worth billions of dollars annually. This economy is based on the harvesting of non-timber forest products, such as the hunting of large and smaller forest animals for sport or subsistence, and also the trapping of fur-bearing mammals. Other forest activities also support large economies through outdoor recreation by local people and tourists. These activities include skiing, the use of all-terrain vehicles and snowmobiles, hiking and trekking, and natural-history pursuits such as birding and botanising.

However, Canada is an extremely large country, and national-level statistics hide important regional differences. In fact, some regions of Canada have been extensively deforested. These are the southern areas where Canadians live in the highest density, mostly within about 200 km of the southern border with the United States. Many native species and some natural ecosystems in these southern regions are at grave conservation risk. In these regions of Canada, deforestation and afforestation are important issues, notwithstanding the relatively low amount of deforestation of the country as a whole.

Economic and ecological benefits of afforestation

Afforestation projects that convert non-forested sites or landscapes to a forested condition can yield great economic and ecological benefits. The benefits fall into three broad categories:

- an improved resource of tree biomass – a potentially renewable source of energy and material
- enhanced ecological functioning, such as clean-water and clean-air services and increased carbon storage
- provision of additional habitat for indigenous biodiversity

From an ecological perspective, the benefits of a particular afforestation project depend on several interacting factors. One is the condition of the land to be rehabilitated, particularly its degree of ecological degradation — the greater the degradation, the larger the potential benefits of afforestation. The kind of afforestation project is also important. Is the intent to develop a high-yield plantation of a particular tree species, possibly an alien one? Or is it to reconstruct a facsimile of a natural forest appropriate to site conditions and biogeography. If it is the latter, then additional considerations include the degree of conservation risk of the forest type being developed, and of the species it is expected to support.

I would like to illustrate these issues, using case material from Canada.

An improved resource of tree biomass

This benefit is obvious — afforestation increases the amount of timber available for harvesting as a source of energy, paper, and lumber. In Canada, however, this is not such an important benefit, because we still have an extensive cover of forest. In more heavily deforested countries, however, the resource benefits are more substantial and important.

Foresters can rather easily predict the rate at which stands will grow. Important variables affecting productivity and the length of the harvest rotation include site quality, climate, management practices, intervening disturbances, and the end-use of the biomass (the rotation length is relatively short for pulpwood, but is longer for sawlogs). These issues are examined in detail in many publications, including Stinson and Freedman (2001) and Freedman and Keith (1996).

Enhanced ecological functioning

Ecosystem functioning provides important services to both the human and natural economies. Areas of forest provide, for example, enhanced control over erosion, improved hydrological functioning and cleaner water, and carbon storage as an offset to some anthropogenic emissions of greenhouse gases. The carbon-storage function is illustrated in Figure 1, which shows successional models for coastal Douglas-fir (*Pseudotsuga menziesii*) forest under four management scenarios:

(1) *Maximum sustained yield (MYS) for pulpwood* – this involves relatively short-rotation forestry, which provides moderate carbon benefits associated with the average forest biomass over the rotation period.
(2) *MSY management for sawlogs* – in addition to forest biomass, this scenario provides offsets associated with carbon stored in longer-life consumer products (such as furniture and timber used to construct homes). There is also some fossil-fuel displacement if wood waste from the sawmill is burned as bioenergy
(3) *MSY management for biofuel* – the harvesting of forest biomass specifically for use as an industrial or smaller-scale energy source results in large and cumulative carbon benefits through the displacement of fossil fuels that might otherwise have been used to generate electricity or heat.
(4) *Protected forest carbon reserve* – this scenario provides the largest carbon-storage benefits, because the forest is allowed to aggrade into an old-growth condition (under the warm-temperate and humid climatic conditions of the western coastal ecozone illustrated, the living and dead biomass in old-growth lowland forest will continue to accumulate for several centuries).

Figure 1 is taken from a study of four forest regions across Canada plus the prairie agricultural region (Stinson and Freedman, 2001). In that study, the carbon-offset benefits of afforestation are particularly large in the coastal region depicted here, because the relatively rapid growth rates and humid climate favours the development of older forests. However, large carbon benefits also occur with afforestation projects in the other kinds of forest ecosystems examined. Although the rate and amount of carbon storage vary across forest regions and with management strategy, the largest benefits are associated with protected areas (as are the greatest biodiversity benefits; see below). Of course, timber harvesting also allows conventional economic benefits to be gained through enhanced access to raw resources; these do not occur with protected areas, although there may be economic benefits associated with outdoor recreation and ecotourism.

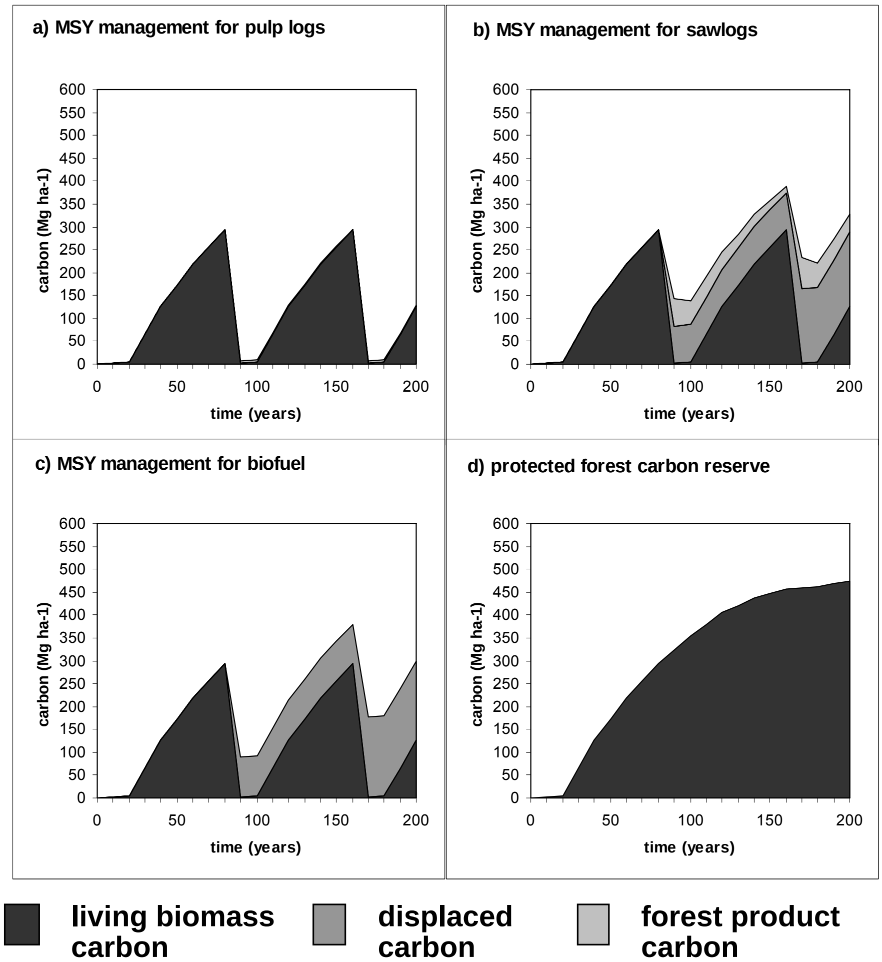

Figure 1. Carbon storage in coastal Douglas-fir forest in British Columbia. Four management scenarios are modelled: (a) maximum sustained yield for pulpwood; (b) MSY management for sawlogs; (c) MSY management for biofuel; and (d) protected forest carbon reserve. Modified from Stinson and Freedman (2001).

Clearly, afforestation in rural areas provides important benefits in terms of environmental services. It should also be noted that planting trees to enhance an urban forest also yields useful results. For example, studies in Halifax, Nova Scotia have shown that the unit-area carbon storage in mature urban forest in residential areas may rival that of rural forest (Freedman *et al.*, 1996). Well-placed urban trees also reduce wind speeds near buildings, helping to conserve heat in winter, and in the summer they provide cooling by shade and transpiration. Urban trees also provide habitat for urban wildlife, as well as improved aesthetics (Freedman and Keith, 1996; Turner *et al.*, 2005).

Habitat for biodiversity

In general, forested habitat supports a much higher species richness (number of species) and density (species/m^2) than does non-forested habitat. For this reason, almost all afforestation projects will provide large biodiversity benefits — even monocultural plantations will provide habitat for some native species. The biodiversity benefits are, however, much greater if an afforestation project is designed to emulate forest that is natural for the ecoregion.

Conifer stands in relatively northern regions, whether afforested naturally or by plantations, begin with a species-rich ground vegetation. However, as these stands grow an over-topping coniferous canopy, they develop a simple structure and a sparse understorey dominated by feather mosses and lichens (commonly including the mosses *Pleurozium schreberi* and *Hylocomium splendens,* the liverwort *Bazzania tribloba*, and various lichens in the genera *Cladonia* and *Cladina*).

The broad patterns of community-level richness and diversity of the ground vegetation of plantations of native conifer species examined in New Brunswick are summarized in Table 2. The highest levels of plant biodiversity (in terms of species richness, density, or diversity) occur in 6–8 year-old plantations, and they then decline to lower values as the stands age and the overtopping canopy exerts severe stress on lower-growing vegetation. The oldest plantations available to study in this case were only 21 years, but it is expected that even lower levels of plant biodiversity would occur in older stands. This would be caused by the increasingly dense shade cast by the conifer-forest canopy up to the anticipated harvest-rotation period of 40–60 years. Feather mosses and some lichens can tolerate those stressful shaded conditions, but most species of understorey vascular plants are not so tolerant.

Table 2. Ground vegetation in conifer plantations and natural forest in New Brunswick.

Age (years old)	Species richness (spp/site)	Species density (spp/m2)	Species diversity (H')
Plantations			
3–5 (n=4)	95 (77–146)	14.3 (11–16)	3.1 (2.7–3.5)
6–8 (n=4)	141 (124–170)	18.9 (18–21)	3.3 (3.1–3.5)
13–25 (n=2)	105 (98–112)	16.9 (15–19)	2.7 (2.4–2.9)
18–21 (n=2)	89 (80–98)	11.7 (10–12)	2.4 (2.3–2.4)
Reference mixedwood forest			
~70 (n=8)	99 (74–141)	13.4 (11–17)	2.8 (2.4–3.0)

Lichens, bryophytes, and vascular plants were sampled (average and range are given). Only 5 alien species (range 2–9; none abundant) were encountered per plantation, and essentially none in reference forest.

Afforestation to restore ecosystems-at-risk

Multivariate analyses can be used to sort the plant "communities" occurring during plantation succession. One such analysis used the average site cover of species of ground vegetation among 20 stands in New Brunswick. The analysis essentially separated the reference stands from the plantations, and the latter according to their age. Almost all of the prominent species in that study are indigenous.

Of course, many species of animals also utilize afforested habitats. For example, plantations in New Brunswick are used for breeding by many species of native birds (Table 3). As with the vegetation, the species composition and relative abundance of birds changes during succession, with relatively young plantations being used by species different from those typical of mature habitats (see also Freedman *et al.*, 1994, 1996 and Johnson and Freedman, 2005). In general, plantations provide wild life with habitat that is structurally simple, in terms of: (a) the age- and size-spectra of trees, (b) plant species composition, (c) vertical & horizontal complexities of biomass distribution, and (d) the abundance of woody debris, snags, and cavity trees. The lack of cavity trees and large woody debris for dependent species is a particular problem in plantations.

Particularly large benefits to native biodiversity can be gained if afforestation projects are designed to provide habitat for species-at-risk, or to emulate natural ecosystems that are endangered. For instance, several of the forest ecosystems natural to Canada are now critically endangered because they have been excessively converted into anthropogenic land-uses. This is particularly true of Carolinean forest of southwestern Ontario, Garry-oak forest on southern Vancouver Island, and any kind of old-growth forest in eastern Canada. The Nature Conservancy of Canada (NCC), an environmental charity, is helping to conserve these at-risk ecosystems by acquisition and restoration projects.

One case involves the restoration of forest dominated by Garry oak (*Quercus garryi*). In Canada, this kind of forest only occurs in a southern zone of relatively warm and dry climate on Vancouver Island. Unfortunately, urbanization and agricultural development have destroyed most of the Garry-oak forest and its associated ecosystems (a natural mosaic of oak savannah, mixed forest, prairie, coastal grassland, and rocky outcrops). In the Canadian context, these are "hotspots" of biodiversity that support many dependent species-at-risk. Only 5–10% of the global habitat survives, and only 1–2% of that in Canada, and there are more than 100 designated species-at-risk (G1/G2/S1/S2).

Table 3. Breeding birds in natural, mixed-species forest and in spruce and pine plantations in New Brunswick.

Species	Plantations				Forest	
Age	3	6	7	15	60	60
Yellow-bellied Flycatcher *Empidonax flaviventris*	0.0	0.0	0.0	6.9	4.1	1.3
Alder Flycatcher *Empidonax alnorum*	0.0	5.3	4.3	13.4	0.0	0.0
Hermit Thrush *Hylocichla guttata*	0.0	0.0	0.0	2.0	2.2	2.6
Magnolia Warbler *Dendroica magnolia*	0.0	1.9	0.0	13.4	9.3	2.6
Yellow-rumped Warbler *Dendroica coronata*	0.0	0.0	0.0	5.5	2.2	1.3
Black-throated Green Warbler *Dendroica virens*	0.0	0.0	0.0	0.0	2.2	5.5
Blackburnian Warbler *Dendroica fusca*	0.0	0.0	0.0	0.0	4.5	6.0
Common Yellowthroat *Geothlypis trichas*	0.9	5.5	9.2	15.3	0.0	0.0
Song Sparrow *Melospiza melodia*	4.8	4.4	7.9	0.0	0.0	0.0
Lincoln's Sparrow *Melospiza lincolnii*	4.4	1.2	17.2	6.0	0.0	0.0
White-throated Sparrow *Zonotrichia albicollis*	0.0	12.6	5.3	8.4	1.5	0.4
Northern Junco *Junco hyemalis*	3.5	1.0	0.8	2.5	2.2	0.4
Total bird density	15.7	53.9	47.2	102	57.8	50.6
Number of species	16	20	22	38	42	32

Only abundant species are listed. Data are pairs/10 ha; stand age is in years. Modified from Freedman (2005).

The Nature Conservancy of Canada is attempting to acquire the best surviving stands in private ownership, but they all need ecological rehabilitation. The remnant stands are relatively small and are also degraded by invasive aliens. As such, necessary stewardship requires making some of the stands “larger” by afforesting adjacent agricultural land, while also controlling the alien species, particularly the shrub, gorse (*Ulex europaeus*). The first afforestation project is only 3 years old. It is showing initial signs of success, in terms of establishing native species dependent on the habitat type, but decades of relatively intensive follow-up stewardship will be required, particularly to control the abundance of invasive alien plants.

Another case involving the Nature Conservancy of Canada is located in the Carolinean forest zone. This forest only occurs in a region of relatively warm climate in extreme southern Ontario, but it has the country’s highest site capability for agriculture. The resulting agricultural conversion, along with relatively extensive urbanization, means that >95% of the natural habitat of the Carolinean zone has been lost. Consequently, the region has many at-risk ecosystems and species. NCC is working in this region to acquire the best privately owned stands of natural forest. Typically, however, the stands are relatively small, and so NCC is beginning to enlarge some of them by afforesting adjacent agricultural land.

One afforestation project involves about 450 ha at Clear Creek. The remnant stand of natural habitat is mostly floodplain forest that supports populations of numerous at-risk plants and animals. NCC has also acquired adjacent cultivated land, with the intent of "enlarging" the natural forest to increase the conserved habitat and also to restore an ecological connection to the shore of Lake Erie. About 69 ha have already been planted to trees, and an additional 50 ha will be started in 2005. The methodology involves the creation of a pit-and-mound microtopography to emulate the natural disturbance dynamics of windthrow of individual large trees. Some of the pits are made relatively large to emulate the ephemeral ponds characteristic of natural forest in the ecozone. The afforestation involves the planting of seedlings or nuts of 16 native trees, the seeding of indigenous understorey species, and management to facilitate the natural regeneration of other native plants. The stewardship also requires a longer-term commitment to monitoring and adaptive management to ensure conservation "success".

The Nature Conservancy of Canada is also planning to work at a more "landscape" scale in the Carolinean region. Within a designated project area, the intent is to acquire all surviving privately owned tracts of natural forest, and to then afforest the intervening cultivated land to develop corridors and increase the total forested area. The project area is in the most biologically diverse region in Canada, and is one of two areas containing the highest densities of species-at-risk in the country. The project region already has a core of protected areas, amounting to about 4,900 ha. NCC is now planning to acquire additional privately owned habitats in a natural condition, as well as the intervening cultivated land for ecological restoration by afforestation in order to develop linkages and expand the overall conserved habitat. The afforestation would involve a diversity of native tree species. By 2005, an area afforested in 1995 had developed to the degree that it was already being used by interior bird species of the adjacent older forest, as well as other biodiversity "targets" for the project. These encouraging results are stimulating plans and fundraising for more extensive afforestation efforts in the project area. The medium-term goal is to triple the amount of fully protected area through a combination of securement of existing natural habitat and ecological restoration. This will result in by far the largest protected area of forest in this endangered Canadian ecoregion.

Summary

Afforestation yields three classes of economic and ecological benefits: (1) an improved resource of tree biomass, which is a renewable source of energy and materials; (2) improved ecological functioning, such as increased carbon storage and cleaner water and air; and (3) provision of

additional habitat for indigenous biodiversity. These are important and worthwhile benefits, and are excellent reasons for funding much higher levels of afforestation activity. In most cases, the ecological benefits of afforestation are much greater if projects are designed to emulate stand types that are natural to ecoregions.

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1.2 The impact of afforestation on bird diversity in Scotland

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Abstract

In Scotland, afforestation from the mid 20th century onwards had a substantial impact on bird communities. Initially, even-aged, single species conifer plantations dominated new forests. Bird communities of heathland and grassland, were progressively replaced with those of conifer thicket and then mature forest. There were also edge effects leading in the long-term to declines in birds outside plantations, including scavengers, wading birds, gamebirds and predators. The diversity in woodland birds was severely constrained by a lack of forest heterogeneity and the bird communities of new forests were dominated by ubiquitous species, in contrast to the declining open country communities, which included some charismatic species.

In the late 20th century, a reappraisal of forests endorsed their wider value as important environments for both people and wildlife. The remit of forest authorities expanded to include biodiversity so both forest policy and management changed. In some regions, forests of native trees were promoted and alien trees purged. In other regions, commercial forests of alien trees were retained but with an enhanced diversity in species and age-structure. The emphasis in management has shifted towards forest heterogeneity and the new quest is for an understanding of how to improve forest management for 'priority' specialist bird species.

Keywords: Afforestation, birds, biodiversity, plantation forestry, habitat mosaics.

Introduction – afforestation in Scotland

Five thousand years ago, much of Scotland had tree cover with extensive natural forests of birch (*Betula)*, alder (*Alnus)*, Scots pine (*Pinus sylvestris)*, oak (*Quercus)* and elm (*Ulmus)* (Petty & Avery 1990). From 1600 AD, exploitation for timber and fuel reduced the extent of forests, and then heavy grazing by domestic stock and deer prevented adequate tree regeneration. Moreover, in many areas vegetation was regularly burned to prevent scrub and woodland regeneration in favour of grazing for livestock (particularly sheep (*Ovis)*) and latterly, heathland for game (red deer (*Cervus elaphus)* and grouse). By the mid to late 19th Century, the

Scottish forest had been fragmented and reduced to between 4% and 5% of land cover. Land managers then started to protect young trees from ungulate grazing, and the first tree plantations were established. The rate of forest expansion was slow, so in 1947 'The Forestry Commission' was established to plant state-owned forests on a large scale. Forest cover increased from 6 to 7% over the next decade but then accelerated with the development of improved methods for the mass propagation and establishment of plantations of alien conifer species. Further fuelled by fiscal measures (financial incentives for the private sector) forest increased to 15% of land cover over the next 30 years.

From 1958 to 1988 new forest comprised almost totally of extensive, even-aged, single species plantations using alien conifers – mainly (68%) Sitka spruce (*Picea sitkensis)* but also much Lodgepole pine (*Pinus contorta)*. Harvested woodlands were restocked, and ancient native woodlands (often remnants with only scattered trees) were under-planted, using the same exotic tree species. From 1988, national forest policy shifted and there was emphasis on plantations of native tree species with a high proportion of broadleaves. From the mid 1990s there was additionally an increased expansion of the remnants of semi-natural woodlands by purging previously planted exotics and protecting the natural regeneration of natives from fire and from grazing or browsing sheep and deer.

The dramatic changes in forest policy, away from even-aged plantations of alien conifers, towards the encouragement of native species and natural forest regeneration processes, was driven by a change in public attitude towards forests (comprehensively reviewed in Warren 2002). The initial planting had been to rapidly establish a strategic reserve of timber – the forests were considered principally for commercial production. The subsequent financial incentives offered during the 1980s were ultimately so beneficial as to encourage afforestation by the private sector purely to get tax relief and subsidiesy from the public purse. By then, the enormous scale of plantation forestry was clear, as was the irreparable damage accruing to scarce habitats and species of international importance. The well-documented impact of afforestation on bird populations was used effectively in the high profile debate that ensued because birds had popular appeal. The public discussion became highly polarised and sometimes acrimonious but the use of public money to subsidise forest companies run by corporations for tax benefits and pension funds was clearly questionable and in 1988, the financial incentives were withdrawn and the purpose and context of afforestation reviewed. Thereafter, forests were viewed as multipurpose; the importance of wood pulp and timber decreased in favour of forest as a valuable environment for wildlife and people.

Changes in bird populations associated with afforestation

The studies of bird populations principally used measures of bird abundance amongst a series of plots at various stages in the process of afforestation (chronosequences). The observed differences between forest stages suggested that afforestation of moorland and sheepwalks caused the replacement of open country songbird communities, with those of scrub and then woodland (Table 1) accompanied by increases in both the number of species and overall bird density (Moss et al. 1979, Ratcliffe & Petty 1986).

Table 1. Changes in songbird communities associated with afforestation (from Moss et al. 1979)

	moorland	trees planted	pre-thicket	thicket	pre-felling
Moorland bird species	4	3	3	0	0
Scrub bird species	0	6	9	2	0
Woodland bird species	0	2	7	14	15
Total bird species	**4**	**11**	**19**	**16**	**15**
Density (birds/sq km)	59	105	250	342	371

Wading bird populations of Scottish peatlands were also apparently affected with dramatic declines documented (Stroud et al. 1987). The first to go were dunlin (*Calidris alpine)* that favoured pools rapidly lost during the initial drainage of planting sites. Then golden plover (*Pluvialis apricaria)* were lost from dry heath and bog as trees were planted and ground vegetation became rank. Finally greenshank (*Tringa nebularia)* was lost from peatlands as trees grew and their canopy closed. Only one species of wading bird was gained following afforestation; the woodcock (*Scolopax rusticola)* was a common breeding bird of woodland at that time in Britain, and colonised the new conifer plantations.

Changes in herbivores and their predators took place early in the process of afforestation, associated with the initial removal of large grazing animals, sheep and deer (Table 2). There was an immediate effect in that large mammal carcasses were no longer available for scavenging birds such as raven (*Corvus corax)*; initially leading to poor breeding, but subsequently reducing the breeding population with the loss of pairs in areas that lacked access to open ground and sheep. The other immediate impact of the removal of ungulates was an increase in ground vegetation that then provided much more food for smaller herbivores. There was a period of three to ten years after the removal of ungulates during which the populations of small mammals, red grouse (*Lagopus scotica)* and hares (*Lepus)* increased. The predators of small mammals, including kestrel (*Falco tinnunculus)*, short-eared owl (*Asio flammeus)*, and barn owl (*Tyto alba)* increased dramatically in numbers as field vole (*Microtus)* populations peaked. Golden eagles (*Aquila chrysaetos)* feed on red grouse and hares and their breeding performance improved for a few years until tree growth shaded out ground vegetation and their prey became scarce. Ultimately, following tree canopy closure, grouse, eagles and vole predators declined, often to extinction where no open country remained.

Table 2. Changes in herbivores and their predators associated with the removal of sheep and deer in the process of afforestation

effect	subsequent effect	bird species	short-term consequences (<10 years)	long-term consequences	authority
few carcases	less food for scavengers	raven	poor breeding	population decline	Marquiss *et al.* 1978
more ground vegetation	more food for herbivores	red grouse	increased population	species lost with tree canopy closure	Parr 1990
more ground vegetation	more small mammals	kestrel *Asio* owls barn owl	population increase & good breed-ing	species lost with tree canopy closure	Village 1990, 1981
more ground vegetation	more hares & grouse	golden eagle	improved breeding	poor breeding & population decline	Marquiss *et al.* 1985, Watson 1997

Particularly for birds that range over wide areas, the configuration of plantation blocks was important in that the size and shape of tree blocks affected access to open country. Thus, despite major afforestation in Wales, there was no decline in ravens and the post hoc explanation was that forest blocks were linearly aligned on hillsides; the ravens were sustained by carrion from sheep that remained on the adjacent hilltops at very high densities (Newton et al. 1982). Another study of forest / open ground configuration examined different sized patches of unplanted ground in Southern Scotland and found that small patches did not retain large populations of moorland birds such as golden plover (Rankin & Taylor undated). Unfortunately, the results were far from conclusive because afforestation in the region was so extensive that the small patches of remaining open country were too few to make a statistically balanced sample for comparison.

As well as afforestation impacts on the planted ground itself, there were probably additional forest ‘edge’ effects. Compared with open country elsewhere, moorland adjacent to tree plantations was drier, had longer ground vegetation and fewer moorland birds (Langslow 1983, Stroud & Reed 1986, Avery 1989, Parr 1990). One explanation was that tree plantations lowered the water table, and discouraged burning, leading to dry, rank, less suitable habitat for moorland birds, particularly waders. Another interpretation was that drier ground had been selectively afforested and growing trees did not dry out adjacent ground. Irrespective of whether there was a drying effect of growing trees, the loss of terrestrial species such as red grouse, adjacent to plantations was real and might have been caused by impoverished breeding success rather than poor feeding. Parr (1990) looked at this specifically and found that moorland birds adjacent to plantations did indeed have poorer breeding success, associated with more predators there (foxes and corvids). Avery et al. (1989) used artificial nests to show that predation was high adjacent to forestry plantations.

There were also further, subtle hydrological impacts of afforestation possibly affecting water birds (Stroud et al. 1987). Forestry activities, including ploughing to the margins of waterways and tree crop fertilisation, led to the runoff into freshwaters of silt, nutrients and atmospheric pollutants (reviewed in Nature Conservancy Council 1986). There were well-established effects on both invertebrates and fish, which in turn could reduce the numbers of riparian birds and piscivorous birds.

In summary, the impacts of afforestation on songbird and wading bird communities were straightforward – the replacement of open country communities with those of scrub, then woodland. There was a loss of scavenging birds and a short-term increase in herbivores and their predators following the removal of grazing ungulates. There were additional effects on a regional scale, dependent on the configuration of the mosaic of forest plantation and open country, and on forestry practices influencing freshwater hydrology.

Losses and gains

Afforestation was controversial because it led to high losses and relatively small gains in bird conservation. Nature conservationists in the 1980s were experiencing significant losses in that scarce semi-natural habitats were being destroyed. The land that was being planted with trees was mainly upland farms and rough grazing – areas that at that time were the remaining large expanses of semi-natural habitat in Scotland. Intensive agriculture had substantially reduced the wildlife value of arable farmland, which for both conservation and productivity reasons would have been more suitable for conversion to forest. It would have produced better quality timber. However, it was such productive farmland as to be too expensive to purchase for forestry. Afforestation was therefore removing some of the best wildlife and wilderness areas left in Scotland and during the 1980s was destroying much of the wet peatland in the Flow Country of the north by deep ploughing and tree planting. This region held the breeding populations of some scarce and charismatic birds, so it seemed that the most cherished of UK open country bird species were threatened with major decline because of tree planting.

By contrast, gains from this sort of afforestation were small. The argument that coniferous plantations held more species and a substantially greater abundance of songbirds was of no consequence because these were ubiquitous species that could be commonly found elsewhere. It seemed that these new plantations of alien conifers were not providing habitat for scarce or charismatic woodland species. This was not entirely true. The new forest provided nesting sites for some scarce birds such as goshawk (*Accipiter gentilis)*, a charismatic predatory species that was increasing (Marquiss & Newton 1982). However, though valued locally, goshawks are an internationally ubiquitous bird. An undoubted gain for Scottish biodiversity was the colonisation of these new forests by crossbills (*Loxia* ssp.) – specialised finches that have crossed mandibles to extract conifer seed from the protective fruiting cones. Formerly, there had only been one conifer species in Scotland with a single species of crossbill exploiting it. Extensive afforestation with exotic conifers provided a diversity of crossbill foraging niches so at least three species of crossbill (including five 'vocal' types) are now breeding there sympatrically (Marquiss & Rae 2002, Summers et al. 2002).

Set against these gains, there was a failure of these new plantation forests to provide habitat for some internationally threatened species, characteristic of native Scottish woodlands. The capercaillie (*Tetrao urogallus)* is a bird of the Scots pine forest that is in decline and globally threatened. The plantation forests of exotic spruce and pine were a poor habitat for capercaillie because of their structural homogeneity. Capercaillie is very heavy bird and requires stout lateral tree branches so that it can perch to graze canopy foliage. More importantly, during spring and summer they require a forest ground cover of blaeberry (*Vaccinium myrtillus)* to provide fresh growing, nutritious shoots for egg-laying hens and invertebrates for growing chicks (Moss & Picozzi 1994). The commercial spruce plantations planted during the 1960s to 1980s lacked heterogeneity; their close stemmed planting produced tree stands bare of ground vegetation and the trees themselves had little spreading canopy and away from edges, only weak lateral branching. Nevertheless, heterogeneity can be contrived through forest management and the retention of semi-natural elements as they arise. Currently, plantations of Scots pine and European larch (*Larix decidua)* are being managed in certain regions of Scotland specifically for capercaillie habitat. Similar strategies might improve Scots pine plantations for crested tit (*Parus cristatus)*, another scarce Scottish woodland bird species.

Changes during the 1990s

Forestry policy in Scotland changed dramatically following on from the removal of fiscal incentives in 1988, and a fall in sawn wood and pulp prices during the 1990s. In 1994, a reappraisal of the role of forests in the UK endorsed their value for people and wildlife. From thence, forests were seen as "multi-purpose", "multi-benefit" and "sustainable" (Warren

2002). They are still important for pulp and timber production, but perhaps even more so for "making a positive contribution to the environment", "creating opportunities for more people to enjoy trees, woods and forests", and "helping communities to benefit from woods and forests" (Scottish Executive 2000). The promotion of biodiversity is now central to land use policies in Scotland and wildlife conservation had an important role in devising regional plans for the placement of forests. 'Indicative Forest Strategies' classified regions into zones that were viewed as 'preferred', 'potential' or 'sensitive' for forestry.

With these systems in place, acrimonious confrontation over forestry issues is now mostly avoided. Forestry is no longer viewed as a major threat for conservation but often as an asset. Afforestation continues albeit at a slower pace and commercial forests continue to use exotic tree species but there is some diversification in species and structure. Afforestation and second rotation tree planting favours native species and includes a high proportion of 'broadleaves'. Where practical, forest management favours 'continuous cover forestry' (Mason et al. 1999) and natural regeneration.

There is now an acknowledgement of previous mistakes and an attempt at reparation as some valuable habitats are receiving restoration management. In our remnants of semi-natural forest, exotic trees are purged ('cut to waste') and natural regeneration encouraged. Most importantly, some open country and mire is being reinstated – trees cut and drains blocked – in an effort to restore as much as is practicable, the most precious of peatlands in the Flow Country of northern Scotland.

The impact of current forest policy and practice on birds

The current emphasis on biodiversity in forest policy and management will inevitably benefit bird populations but two events have provided guidance for such conservation. Firstly, in 1995, national and regional priorities were established for the conservation of specific UK habitats and species, and 'Biodiversity Action Plans' for Scotland followed (Usher 2000). There are consequently named high priority, open country bird species that can be specifically taken into account during the afforestation planning process (Indicative Forestry Strategies). Similarly, there are named woodland bird species that can now be considered in particular forestry management plans. Secondly, of 33 woodland bird species monitored by the British Trust for Ornithology since 1970, 21 specialist species have shown substantial decline (Eaton et al. 2004, Fuller et al. 2005). We thus have a list of priority bird species to take into account when considering forest planting and management in Scotland.

There have been studies of songbird communities across Britain that suggest very large differences between forests associated with a range of features such as latitude, altitude, dominant tree species, under-storey structure, the amount of deadwood and the proportion 'over mature' woodland (Lennon et al. 2000, Newton 1986, Bibby et al. 1989, Petty & Avery 1991). There is also the suggestion of large differences between first and second generation planted forests associated with the greater structural diversity of the latter (Ratcliffe & Petty 1986) including the amount of edge (Patterson et al. 1995). Forest management can influence many of these features but is currently disadvantaged by only limited information on management for a few priority bird species (Currie & Elliott 1997).

Forest management may now focus on the complex ecological requirements of woodland specialist bird species, but help from ornithologists is required to supply further ecological information to underpin such management (reviewed in Fuller & Browne 2003). At this early stage three approaches seem sensible:

- To manage forests for heterogeneity at various scales.
- To manage forests to mimic natural features, such as forest bogs, wood pasture, patchy natural regeneration, 'old growth' and standing deadwood.
- To carry out autecological studies of priority birds to specify their particular requirements.

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1.3 Modelling change in ground vegetation from effects of nutrients, pollution, climate, grazing and land use

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Abstract

ForSAFE for modelling biogeochemical cycles (water, acidity, base cation, nitrogen and carbon) in terrestrial ecosystems, was modified incorporating the effects of: nitrogen pollution, acidification, soil moisture, temperature, wind chill exposure, light and shading by trees, grazing by animals, competition between plants, above ground for light and below ground for water and nutrients on the ground vegetation. The model calculates the response of 42 ground vegetation plant species groups, each representing its class of plants and 7 tree species. The model was tested and validated at 16 integrated level II forest monitoring sites across Sweden and used to assess the effect of acidification and nitrogen pollution in relation to other factors such as climate change, forest management and changing grazing pressure. The response functions have been derived from single-factor experiments and integrated through the model structure for use on whole systems. The tests with the model suggest that the ground vegetation composition is reasonably well predicted and that the model may serve as a tool for assessing impacts of climate change, acid rain and forest management on plant biodiversity in forested areas.

Introduction

Vegetation change and loss of plant species links to almost all environmental problems, and biodiversity has been given a high priority in Nordic environmental policies defining a need for modelling of biodiversity aspects. Up to now, the ecological effects originating from forest management, afforestation, acid deposition, eutrophication and global climate change, have been investigated independently, because of the lack of integrated models.

Objectives and scope

The focus of this study is modelling of ground vegetation composition and soil stocks of carbon, nitrogen and base cations in terrestrial ecosystems and how this changes with time as a result of pollution inputs, climate change and forest management. We want to use the model development process to build understanding of the vegetation dynamics and the feedback structures. In the continuation it will be used for integrated sustainability assessments of anthropogenic impacts on ecosystems. The points above necessitate the development of an integrated model coupling the acidity cycle, nitrogen cycle and carbon cycle with forest management and growth.

The integrated model; ForSAFE-VEG

Model components used in ForSAFE-VEG have partly been developed at Chemical Engineering, Lund University; ForSAFE (Wallman et al 2004); Soil chemistry, geochemistry, forest growth and production (integrates biogeochemistry and soil processes, nitrogen/carbon cycle under managed forestry of tree size and age cohorts) and the ground vegetation response model VEG. In addition, a revised version of the PnET (Aber et al 1985) and a rebuild of the Swedish HBV hydrological model including snow and frost were used (Wallman et al 2004). New models for organic decomposition and soil temperature were developed for ForSAFE integration (DECOMP: Wallman et al 2004). The ForSAFE-VEG models contain the following integrated ecosystem components:

- The tree vegetation layer
- The ground vegetation layer
- The soil chemistry and geochemical processes
- The soil stocks and cycling of nutrients and carbon
- The hydrology and soil temperature

The model calculates changes in the present state at plot scale caused by biogeochemical responses to ambient conditions and local competition at the site and change in ambient habitat conditions due to biogeochemical processes. Wildlife dynamics (Helge-model) is external to the model. The included pre-existing biogeochemical models have been validated and applied successfully in a regional context (Warfvinge and Sverdrup 1992, Sverdrup and Warfvinge 1993, 1995, Sverdrup et al 1996). They are linked with a forest growth model and a vegetation response model. In order to synthesize an integrated multiple stress system, ForSAFE-VEG (Figure1) provides simultaneous predictions of climate change, soil acidification and eutrophication with vegetation changes and effects on forest growth.

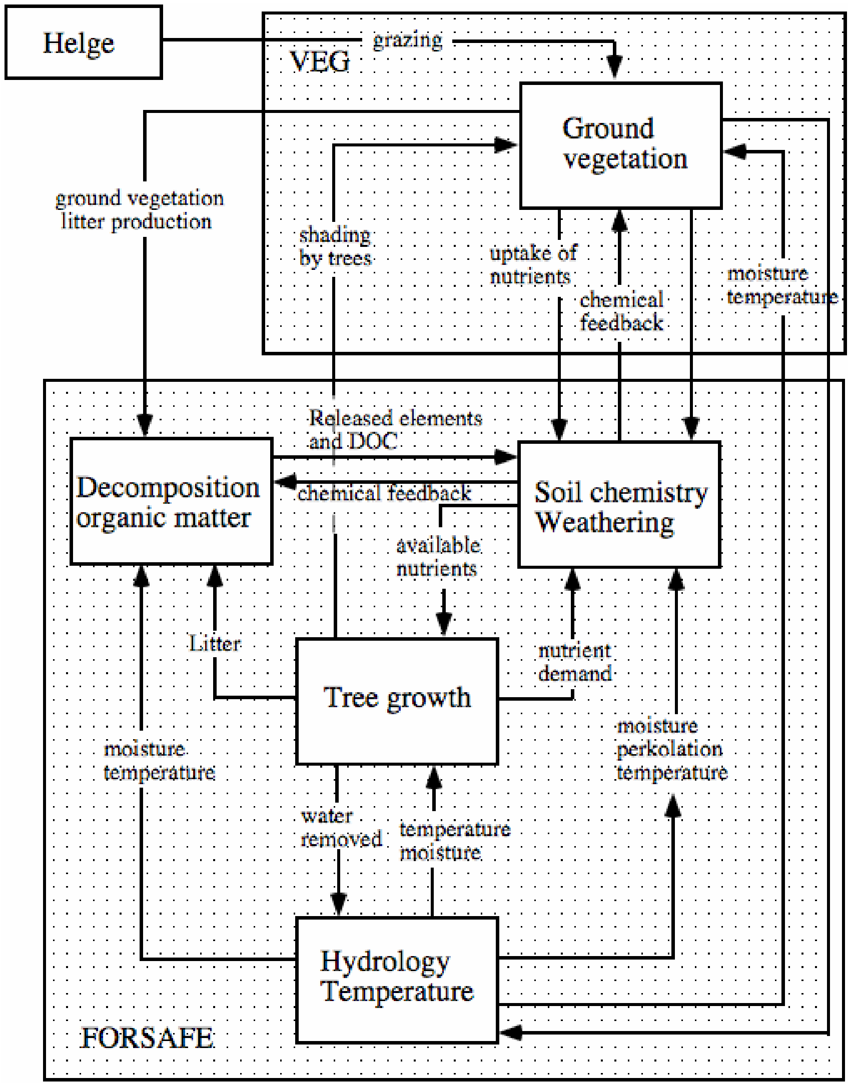


Figure1. Overview of the structure of the ForSAFE-VEG model and the flow of iteration inside the model

ForSAFE is a fully mechanistic with nitrogen- and carbon-cycle submodels as well as predictions of forest growth under production management. Inputs are deposition fluxes of S, N, base cations and water, plant uptake, climate parameters and soil properties, mineralogy or alternatively the weathering rate, some of these with vertical resolution. Outputs are soil chemistry, decomposition rates, mass fluxes and weathering rate per soil layer. The change in vegetation composition state depends on two factors: the delay caused by survival of individuals in the population for a specific time T. The change is also proportional to the driving force for change, the difference between what is there, the present system state X and what should have been if there were no delays, the immediate equilibrium state XEq. The change in occupancy fraction X is found by combining these into the main equation:

(1) $dX/dt = 1/T\ (X_{Eq}-X)$

where *T* is the delay time of the particular plant group. The equilibrium occupancy fraction *Xeqi* of plant group i in the territory is estimated by using an equation based on competition strength (*S*):

(2) $X_{Eqi} = S_i/\sum S_J$

where X_{Eqi} is the fraction of the territory the plant should have at equilibrium based on its strength S as measured against the sum of the strength of all the other plant groups ($\sum S_J$. X_{Eqi}) it measures itself against in the competition for land occupancy . The strength of a plant group is determined by different strength factors depending on a number of parameters:

1. soil solution nitrogen
2. light reaching the ground
3. soil moisture
4. site soil temperature including wind chill effects
5. soil chemistry
6. grazing by ungulates
7. forest fires
8. forest management and usage

Thus, competition in the model is expressed through:

1. By comparison of competition strength S to sum of others
2. Use of above-ground geometry for light expressed as leaf area index and effective shading height in metres modify the strength
3. Use of below-ground geometry for nutrients, water and exposure to chemistry expressed through soil layer distribution of roots that modify strength

At present, the effect of phosphorus is in the process of being added to the model. In ForSAFE, any number of soil layers may be used, but the normal configuration is to use 4 layers; one organic layer and 3 mineral layers. The response functions are all scaled between 0 and 1, where 1 represents the state of no-effect from that factor. For any plant *i* the individual strength is given by the product of strengths derived from nutrients, strategies and conditions:

(2) $S = f(Nutrients) * f(Water) * f(Acidity) * f(Grazing) * f(Temp) * f(Wind) * f(Light)$

The aboveground competition strategy of the plant for capturing light and preventing others from getting it, is dependent on plant height and its shading capacity. The root competition strategy for capturing water and nutrients, as well as leading to it being exposed to pH and BC/Al in acid soils, is expressed through root distribution at different soil depths, and for this the root weight weighted average of the functional value is used. The response functions are: *f(Acidity)* for soil acidity, *f(Nutrients)* for nitrogen, *f(Water)* for soil moisture, *f(Light)* for the amount of light coming to the ground. The maximum amount of light *f(Light)* is reduced with any occurring shading from trees, as well as the reduction in intensity that occurs as one moves north. *f(Temp)* is the temperature effect, including wind chill, *f(Grazing)* is the effect of grazing by animals, a direct reduction of aboveground plant abundance, f(V) is the mechanical effect of wind to cause damage. For light, temperature and water a generic response curve was adopted, and all response function coefficients are available for all plants listed for Sweden and Iceland.

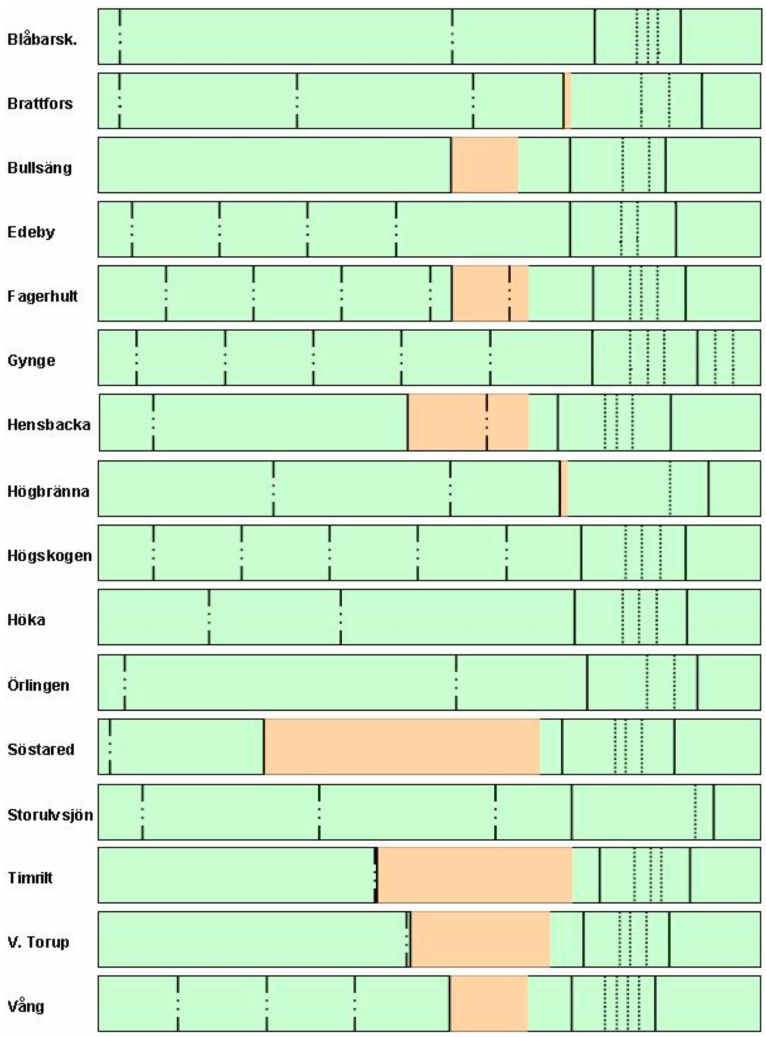


Figure 2. Land use history used in the simulations. Straight line is clrearcut, dotted is thinnings, punctuated is forest fire, brown shade is open land.

Important for the nitrogen, light and water responses are the effect of trees in the forest stand. The N parameters have been derived by a reinterpretation of the results of Ellenberg et al. (1992), Nordin et al (2003) and Bobbink et al. (2004), many unpublished studies and a Delphi process involving the experiences of the authors and two specialists in the field (Ericson and Nihlgård). There are two ways of competing, for light above the ground and for nutrients and water below the ground. Ground vegetation and in particular grass will have a primary production of biomass, depending on nutrients and light. The rate is calculated according to an equation adapted after Fridriksson and Sigurdsson (1983) and Bergthorsson (1985), generalized for Scandinavia. The grass production causes uptake during the season depending on primary production, corresponding to a C/N ratio in the grass of 20. Of the grass production above, all aboveground grass dies every year and is turned to litterfall. Dead grass in litterfall is added to the soil organic matter stock and decomposed with that material. We have identified different indicator plants associated with an equal number of functional plant groups and several indicator tree species for different parts of the Scandinavian area. In addition, earthworms were selected because of their special function and as data for them were available. These are the indicator plants for each of the 42 ground vegetation plant functional groups (Figure 3). All other plants added to the model are added to one of these vegetation classes and to 7 tree species. Vegetation lists are available at present for Sweden, Iceland, Norway, Great Britain and Denmark.

Input data

Trends for temperature and water flow variations are for the time period from 831 AD to 2250 AD, partly as taken from the standard IPCC scenario for the period 1900–2300 (Climate Change 2001, the scientific basis, IPCC). The curves are normalized variation curves, based on the base year 1900. The older history of the sites is not known in detail, but a guess has been shown in Figure2. Figure 4 shows the deposition input at the sites. Before 1820, the harvest was occasional and small in volume at all sites. Forest fires are dependent on moisture and the frequency of lightning and careless humans, they are model inputs. In a typical forest fire, the ground vegetation will be burnt aboveground and ca 40% of the wood in the trees will be incinerated, returning the 40% of the carbon and 60% of the nitrogen to the air. The rest of the nitrogen and carbon becomes litterfall. A total of 80% of the base cations in the burned biomass is released to the soil solution. Of the aboveground vegetation, 80% will be incinerated (carbon and nitrogen gasified, base cations released to the soil solution) and the rest given to litterfall. Pine and birch are adapted to fires and will survive every second fire. Grazing pressure for the four different impact classes, using the Hälge model and the specific grazing response functions, was used. Each plant group has been assigned either one impact class or the no-impact class for grazing. The grazing class includes grazing of ground vegetation and browsing of bushes and trees, as well as effects of trampling.

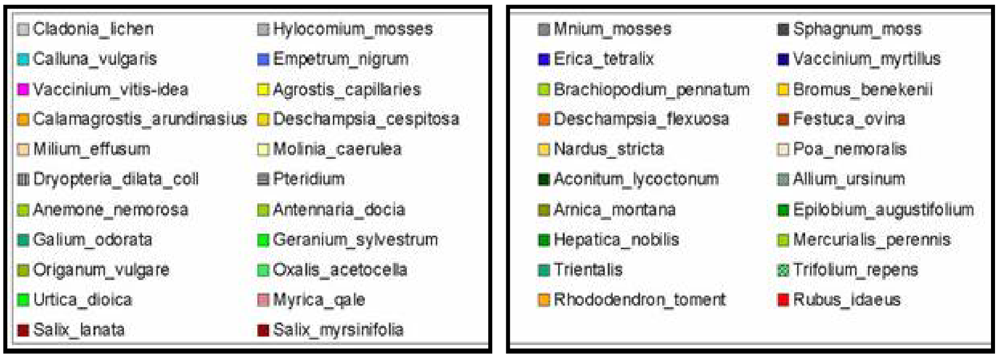


Figure 3. Selection of plant groups chosen and colour code legend for each group, indicating the name of the group indicator plant. . Gray: lichens and mosses; Blue: heather and ling; Yellow: Grasses; Red: Brackens and ferns; Green: herbaceous plants; Brown: Bushes, bush-like ling and thickets.

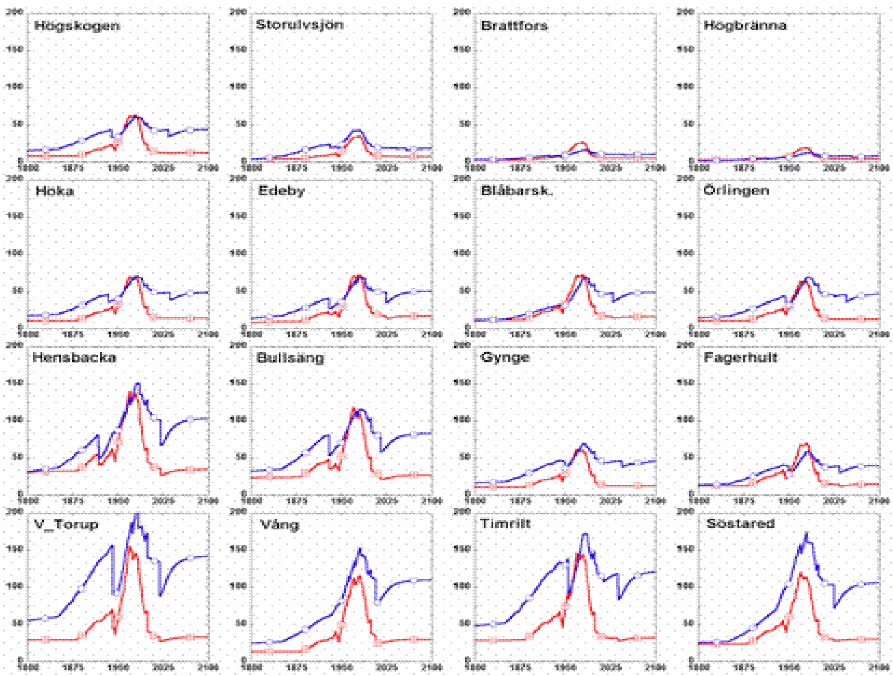
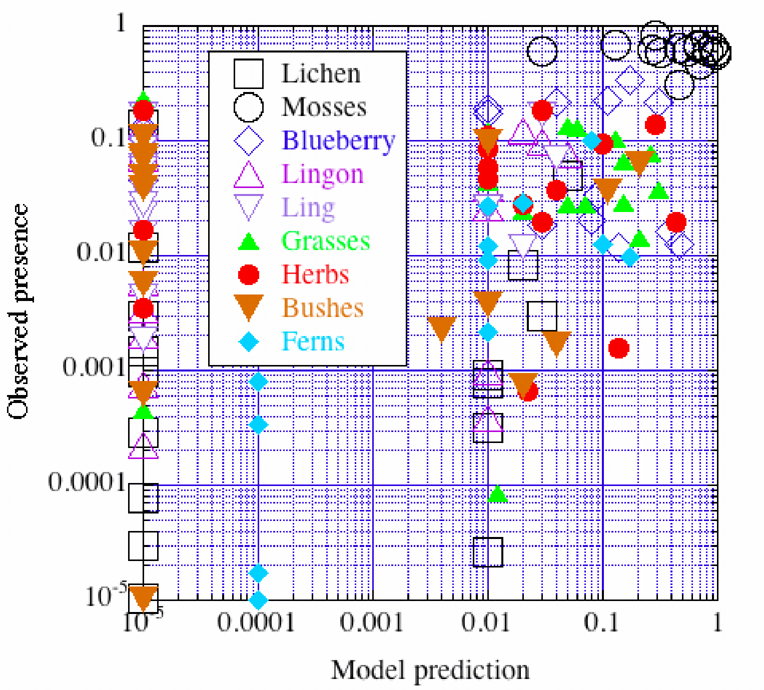


Figure4. Input of sulphur and nitrogen at the sites, for upper left and going right and down: Högbränna, Brattfors, Storulvsjön, Blåbärskullen, Örlingen, Högskogen, Hensbacka, Höka, Edeby, Söstared, Gynge, Fagerhult, Timrilt, Bullsäng, Vang, Torup.

Results

In Figure 6 results have been assembled, the sites have been arranged according to their north-south, east-west orientation in Sweden. The model has been tested in several locations ranging from northern to southern Sweden. These sites are the Swedish forest integrated monitoring sites in the ICP-IM programme. The sites have been described in Martinson et al. (2005.) The validation tests are shown in Figure5 where predictions for 2001 have been plotted versus observed figures for 2001. The runs have only been calibrated on base saturation; all other predictions follow from that, without any further model tuning. Large vegetation changes occur at all sites in the period 1980–2010, so the degree of fit may appear worse than in reality as the timing of the prediction may be slightly off. Overall, the validation shows that the predictions are in the right order of magni-



tude.

Figure 5. A plot of predicted versus observed shows the performance of the model. The observed data is only indicative, thus the predictions should be only evaluated on the order of magnitude of presence.

Conclusions

The tests on field data suggest that the basic structure of the FORSAFE-VEG model and its parameterization is in broad terms adequate and is capable of reasonably predicting ground vegetation composition, suggesting that the included mechanisms are adequately expressed. A plot of observed versus simulated is illustrated in Figure 5. The general trend is that presence or not is correctly predicted and the order of magnitude of presence is more often than not correct. The plot suggests that the model is good in broad terms so far, but much work on fine-tuning remains. Further tests in Denmark, Great Britain, Norway and Iceland (Belyazid *et al* 2007) are encouraging so far. The model performs well under conditions where the inputs are good and the chemical outputs can be verified. The ForSAFE-VEG model in executable version and the source code are available free of charge from the authors.

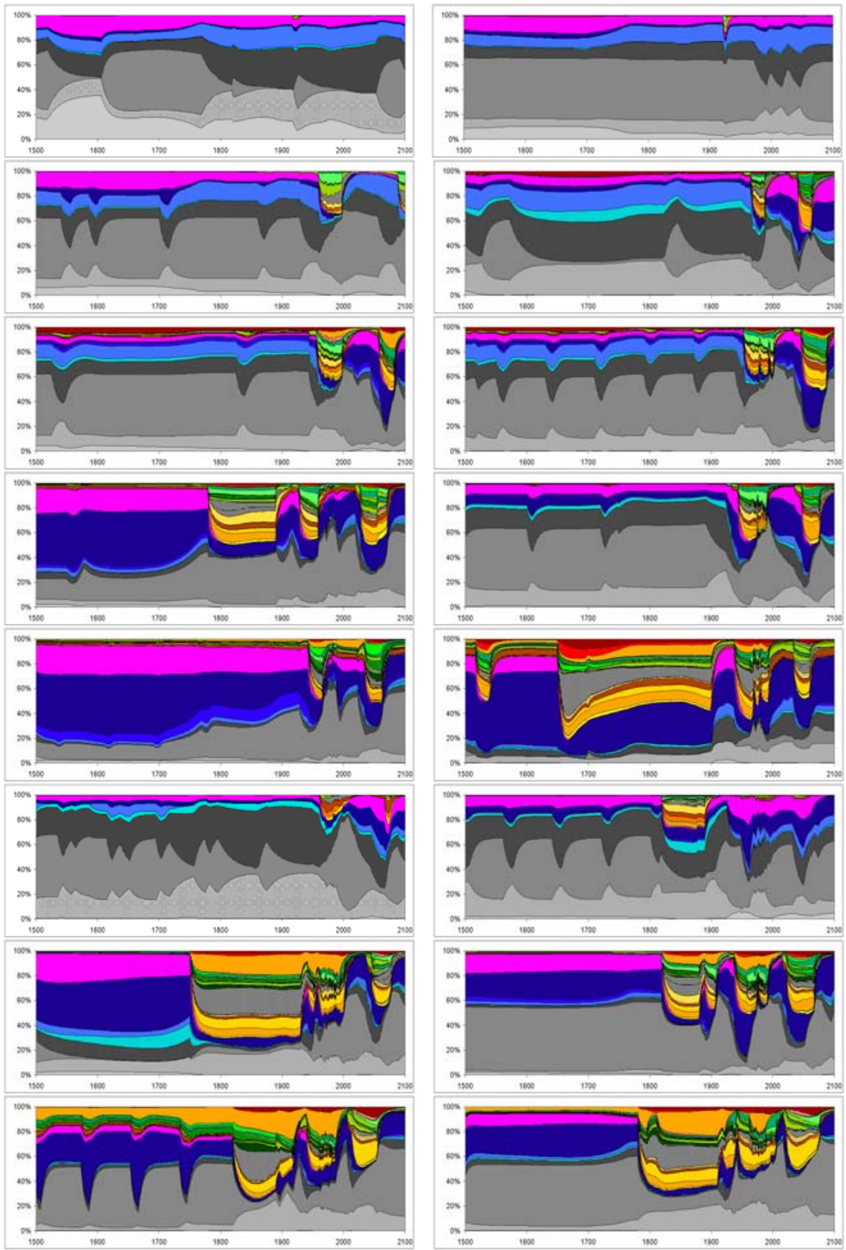


Figure 6. Summary of simulated ground vegetation composition, north (top) to south (bottom) From top right: Högbränna, Brattfors, Storulvsjön, Blåbärskullen, Örlingen, Högskogen, Hensbacka, Höka, Edeby, Söstared, Gynge, Fagerhult, Timrilt, Bullsäng, Vang, Torup. Gray: lichens and mosses; Blue: heather and ling; Yellow: Grasses; Red: Brackens and ferns; Green: herbaceous plants; Brown: Bushes, bush-like ling and thickets.

Acknowledgements

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1.4 The Landscape of Afforestation: From Controversy to Acceptance

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Abstract

This paper explores the way in which plantation forests, once seen as causing serious aesthetic problems in scenic landscapes, have become accepted in countries such as the UK. From the main period of controversy in the 1960s the development of the practice of forest landscape design has enabled forests of plantation origin to be fitted into the landscape. While this practice was pioneered in the UK it has also been applied in other countries. In the UK the period of large-scale afforestation is past but the forests have reached their felling age. This has offered a unique opportunity to redesign the majority of such forests, probably the largest single design project ever undertaken.

Keyword: Plantation, forest design, aesthetics, landscape, perception research.

Introduction

Tree plantations can be found all over the world, from temperate to tropical zones. Major examples of plantation forestry include the extensive use of conifers from the Pacific Northwest of America and Canada in Britain and Ireland, using species such as Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsurga menziesii*) or Lodgepole pine (*Pinus contorta*) planted on former rough grazing or moorland. In Australia, New Zealand, South Africa, parts of South America such as Chile and Argentina, as well as Spain and Portugal, large expanses of Monterey pine (*Pinus radiata*) have been used, native to a narrow coastal belt of California. Eucalyptus species, native to Australia, are used in Southern Africa, South America, Portugal and Chile.

Plantation forests are characterized by species that grow fast and produce higher levels of timber volume per hectare/acre using simplified stand structures. These plantations are typically of one species, although mixtures sometimes feature, are planted all at more-or-less the same time (or within a few years) so that they form even aged stands. They are usually managed on short rotations, calculated either on the basis of the age of maximum mean annual increment (MaxMAI), the time at which volume production peaks before falling off as the stand matures, or the age at which the most economic return is obtained, that of maximum net present value (MaxNPV) according to the forestry economic model using the technique of discounting. Frequently, the intensive silvicultural management of plantations seeks to exclude non-productive species, and employs pesticides, fertilizers, artificial drainage, pruning and other activities to ensure the best growth rates and productivity, as long as it can be proved that there is an economic benefit to carrying out these investments.

Historically, plantations have been laid out in geometric patterns to simplify management. These patterns comprise a series of rectangular compartments, possibly laid out on a strict grid, separated by open strips and fire breaks, the trees being planted in straight rows to facilitate machine operations such as ploughing, draining, weeding or thinning. Records of growth rates, silvicultural activities and harvest products are easy to keep when the plantation is laid out in this way, so such forests can be likened to wood factories geared to the single objective of the production of a standard, predictable product of known performance. Harvesting usually also follows the grid pattern, whole compartments being felled at a time, possibly following a time sequence so that in the ultimate plantation forest, every year the same area is felled producing the same amount of timber. This is replanted and eventually comes to be felled again. The total number of compartments equals the rotation lengths (10, 20, 30, 40, 50 years, etc.) so that a sustained yield of wood can be guaranteed, assuming there are no catastrophic problems such as fire, disease, windthrow, etc. This concept is known as the "normal forest" but it is rarely, if ever, realized because there is not the degree of predictability in a forest plantation that there is in a pig farm or a steel factory. However, the notion as an ideal has been highly influential and has had a major impact on forestry practice over the past several decades.

From the description above, it is easy to see that a plantation forest differs markedly from a natural one in a number of attributes. These differences are often cited as predominantly negative aspects of plantations, in that they are rightly seen as ecologically deficient in comparison with natural forests. A key challenge is to understand how much a plantation should be modified towards the conditions of a natural forest in order to satisfy the requirements of sustainability. Table 1 summarises these differences.

Afforestation in the UK started after the First World War, when the Forestry Commission was founded, in 1919. The rate of afforestation was slow at first but even by the 1930s controversy about the landscape impact arose, centred on the Lake District (now a National Park but not so in those days). This led to the first agreement between the Forestry Commission and an NGO, the Council for the Protection of Rural England, in 1936, where the central section of the Lake District was to be protected from further afforestation.

Table 1. Comparison of plantation and natural forests

	Natural forest	Plantation forest
Species composition	Mixed stands of site native trees, bushes etc.	Single species stands, undergrowth mainly absent
Layout	Irregular stands in size and shape, blurred edges, patterns related to soil, aspect microclimate	Regular, geometric stands with sharply defined edges, site amelioration may be used to even out the influence of site variation.
Rotation length	Forest passes through all successional stages, affected by natural disturbance such as fire, insects, wind.	Forest felled at age probably equivalent to late stem exclusion, active measures used to prevent fire, disease, wind etc.
Stand structure	Complex stand structure may form one to many layers; dead trees, dead wood etc. form the oldest trees in the stand.	Simple stand structures, one canopy layer, dead trees may be removed, little or no dead wood, dead trees only due to self thinning and are not old.
Visual impact	Natural forests are part of the landscape, they express its character. Negative impacts occur at regeneration harvest	Plantations stand out from the landscape and contradict its character during all stages of growth and harvest
Ecological impact	Natural forests provide complex habitat with multiple niches	Plantations provide very limited habitat and few niches

The issue of visual resource management in forestry came to prominence after the Second World War, as the increasing network of highways and mass car ownership enabled large numbers of people to explore the countryside or natural landscapes of North America, Europe and other developed countries (Bell 2004). This period also coincided with greatly increased forestry activity such as afforestation programmes in Britain, Ireland and New Zealand and with increasing levels of timber harvest in the USA, Canada and Scandinavia, especially on public lands. By the mid 1960s public concerns over the appearance of both newly planted forests and logging operations had increased, prompting agencies such as the British Forestry Commission and the United States Forest Service to look for ways in which to safeguard the landscape. The different programmes developed in these countries and the adoption of elements from either or both have had, and continue to have, a wide impact. The models developed in Britain and the USA also followed different routes, partly due to the scale of the forests and forest operations but also reflecting the type of forestry. In the USA logging took place (and still mainly takes place, at least in the National Forest System) in natural forests, where the visual impact of sudden changes to the scenery, occurring over a large-scale landscape, can be very great. While the impact of an individual cut block could have a negative visual effect, the cumulative impact over large areas was often considered to be greater still. In Britain, the programme of afforestation led to significant landscape change but each new planting project was relatively self-contained and there was some degree of flexibility over the layout of such forests. It is this programme and the way it has changed public opinion that is the focus of this paper.

Figure 1. An example of early afforestation in Ennerdale, in England, where the typical plantation layout is visible.

In Britain, with its programme of large scale afforestation and, more recently, felling and replanting of its plantation forests, an approach has been developed based on designing forests to fit into the landscape. This commenced in the 1960s, aimed mainly at new plantations of non-native conifers which were being planted on bare, deforested hills and mountains. The original layouts were often highly regular, with rectangular compartments, vertical fence lines and horizontal upper margins where the trees were planted up to a contour line (see Figs 1 and 2). The introduction of design started when Miss (later Dame) Sylvia Crowe, a well-known landscape architect, was appointed landscape consultant. She started from first principles, considering the major aspects of plantations and how to make them fit into the landscape while remaining practical and economic.

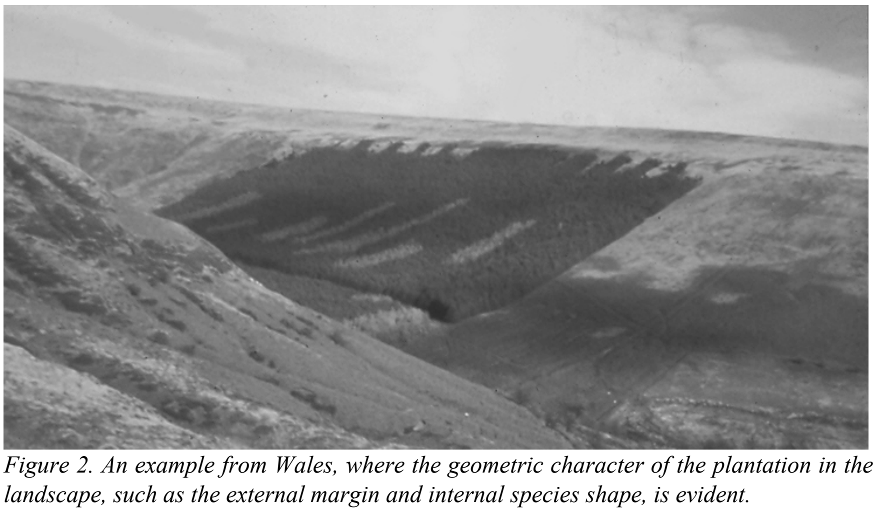

Figure 2. An example from Wales, where the geometric character of the plantation in the landscape, such as the external margin and internal species shape, is evident.

To overcome the artificial appearance of these forests a number of design principles were adopted from landscape architectural practice, for example considering the shape of the forest, its scale and proportion, the degree of diversity of different species, the unity of the forest with its surroundings, how it related to landform and so on. These principles were further developed from the initial work of Sylvia Crowe by Duncan Campbell, Oliver Lucas (Lucas 1991), Simon Bell and later generations of landscape architects working for the Forestry Commission.

Figure 3. An afforestation design on a prominent hill behind the town of Cambelltown in Scotland, presented using a sketch over a photograph.

The principles were first applied to afforestation projects as this was the major activity taking place. The first task is to analyse the landscape setting of the area to be planted and then to make sketches of how the forest could be fitted in, taking into account soil types, ownership boundaries, accessibility and so on (see Fig 3). This eventually developed into a systematic method supported by a training programme for foresters. However, many forests had already been planted to poor layouts before design really got going. The major state programme of afforestation ceased in the early 1980s, although it continued in the private sector until 1988, when the tax rules were changed.

By the 1980s many of the early forests were ready for harvest and the rate of new planting declined, so the focus shifted to designing the patterns of felling, and the opportunity was taken to use the process of gradually harvesting these forests to completely redesign them, especially if they had not had much design input at planting. At this point a series of detailed guidelines on forest landscape design were published, aimed not only at the state forest sector but also at private forest owners (Forestry Commission 1989). These guidelines describe what standards are expected and how to achieve them (see Figure 4). In 1999 a monitoring project across the UK assessed the extent to which the forests had reached an acceptable standard.

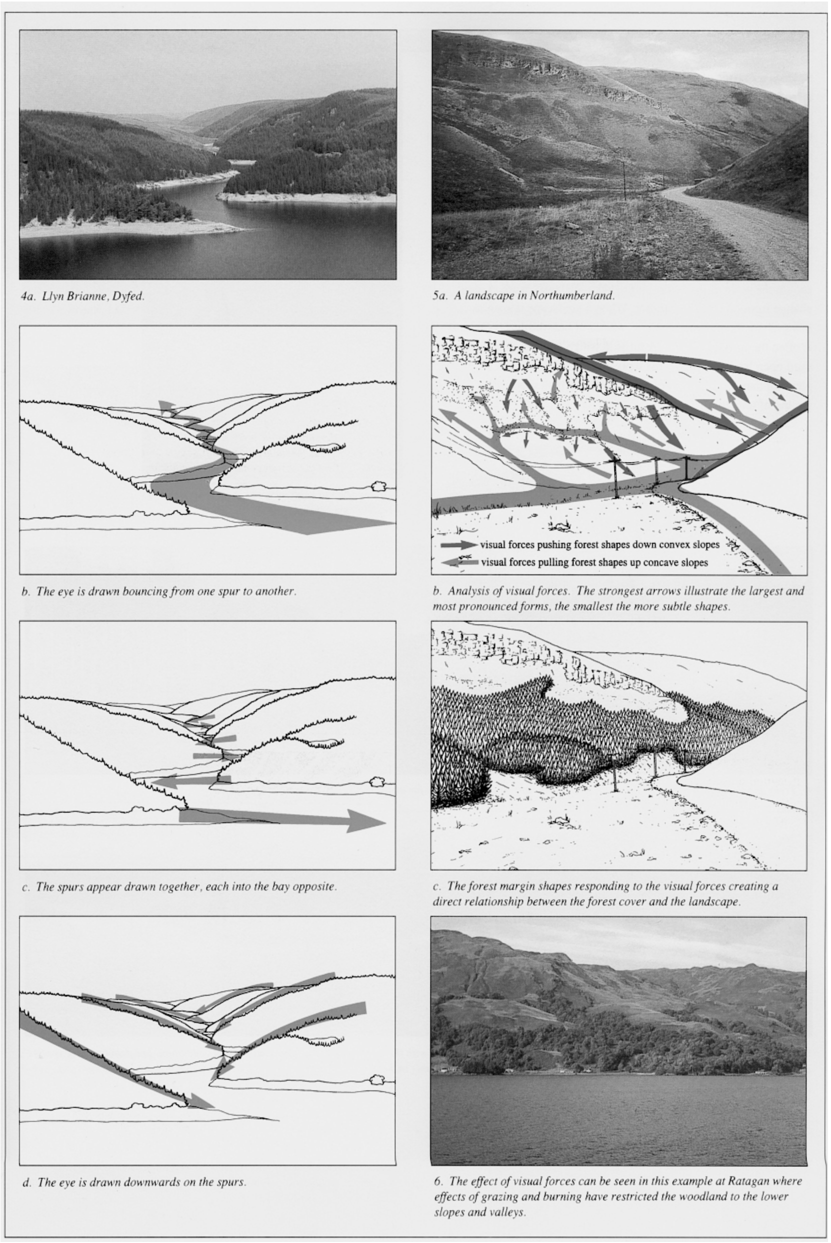

Figure 4. An example of a page from the Forest and Landscape Design Guidelines demonstrating the design principle of "visual force", important when designing forests on prominent landform

This forest design approach was adopted in the early 1990s as the primary forest-level planning method to be used in Britain. Today, sophisticated "forest design plans" are the main tool for planning and managing the forests, and they contain a significant element of redesign to change the original monoculture, even-aged plantations into something more diverse and attractive (see Figure 5) (Bell 1999).

The forest design planning system follows the well-established design process drawn from landscape architecture. Step 1 is to set objectives.

These are not solely for visual quality but also for all the other resource values (this emphasises the integrated character of this approach compared with the single focus on scenic aesthetics of many others). Step 2 is landscape survey (or inventory) where all the information needed for forest planning is collected. Step 3 is analysis. One key type of analysis is that of landscape character, using perspectives as well as plans. This analysis is carried out by applying design principles as descriptors, especially focussing on the main components of the landscape and on the visual problems associated with the existing forest. Step 4 is to develop a design concept, which describes the overall strategy for redesign and the desired future character of the forest. Step 5 is more detailed design, where options for dividing the entire forest into coupes/cut blocks and for replanting it over time are developed and evaluated. The final design is presented using computer-based graphic simulation and submitted for approval in step 6. Steps 7, 8 and 9 are implementation, revision and monitoring.

Since a number of these long-term forest plans have been undertaken since the mid-1980s, their progress has been sufficient that it is possible to see how the landscape has improved and the structure diversified (see Figure 6). These also show that it is possible to plan and implement designs over a very long time.

As well as developing the approach through the route of the professional application of design principles – in other words, treating the issue as a design problem needing a solution instead of a research problem to be analysed – some research into public attitudes and preferences has been carried out. Several projects have looked at both general preferences for forest landscapes and at more specific aspects such as the value placed on landscape improvement. These have been used to calibrate the guidelines and to improve confidence in their application (Bell 1998a and Bell 1998b, Lee 2001).

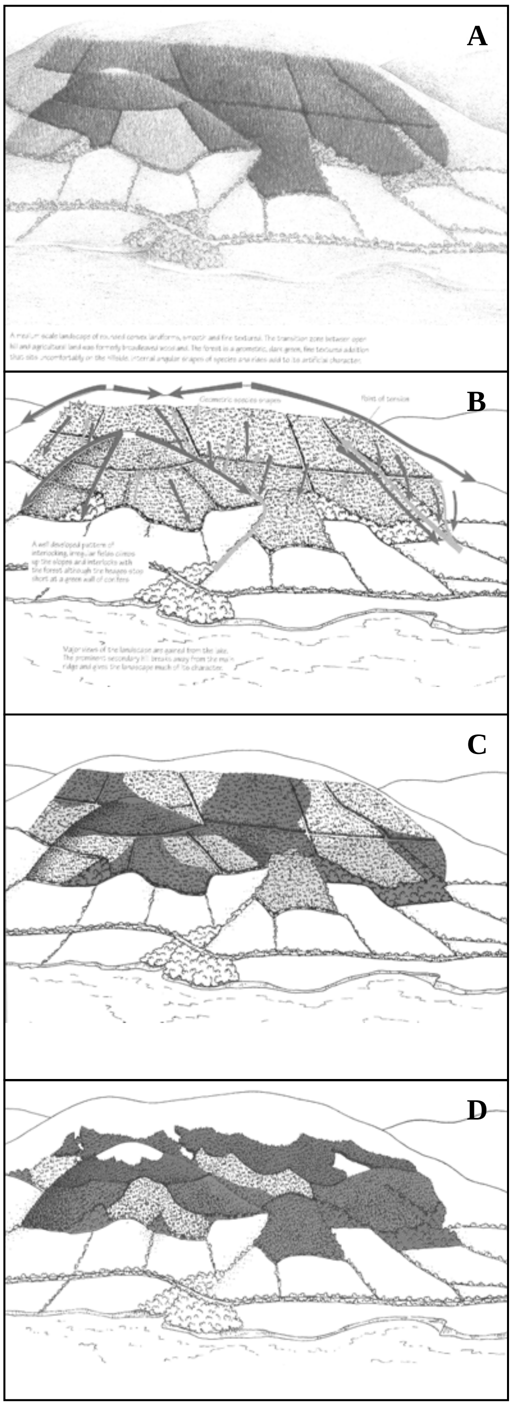

Figure 5 a-d. The sequence of forest redesign. a. shows a typical forest before felling. b. shows the landscape analysis, identifying the various visual problems in the forest. c. is the pattern of felling coupes that break up the geometric structure and are phased over time. d. is the restocking pattern showing the redesigned layout.

Figure 6. The appearance of Strathyre Forest in Scotland, where felling has been in progress following a plan since 1986.

Recent developments have seen a shift away from clear felling as the main silvicultural method towards continuous cover systems. There has also been a programme of restoration of native woodland, both on bare de-forested sites and by converting conifer plantation to native forest be felling and replanting. Integrating aspects of landscape ecology into forest design planning has also been the subject of research (Bell 2003).

Conclusions

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.

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1.5 Forestry and rural development

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Abstract

Forestry is recognised as having an important role to play in rural areas. However, the nature of its contribution to rural development has changed over time as both the understanding of the functions of forestry, and the definition of rural development, have evolved. Consequently techniques to assess this contribution have had to expand in order to address the wide-ranging impacts of forestry. This paper reports some of the results of a recent study undertaken in Ireland to examine the social and economic impacts of forestry in rural areas. The social impacts of forestry in one case study area in Newmarket, Co. Cork, are reported in this paper.

Keywords: Forestry, rural development, social impact assessment, Ireland.

Introduction

Rural areas currently account for ninety percent of EU territory and approximately half of the EU population live in these areas (EC 2004). In the past rural areas were less diverse and sophisticated than urban areas while rural economies were thought to be more unstable and less resilient than their urban counterparts (Kennedy et al. 2001). These characteristics, amongst others, put rural areas at a comparative economic disadvantage to urban areas. Many governments saw agriculture as the key function of rural areas with security of food supply its primary role. It was believed that increasing the output from agriculture would generate sufficient wealth to tackle rural poverty (PIU 1999 cited in Roberts 2002). This view provided the framework for rural development policy for many years and resulted in most rural development policy measures focussing solely on agricultural aspects. However, conditions that existed in rural areas fifty or so years ago are very different to those that prevail today. It is now widely accepted that agriculture is no longer the sole economic driver in rural economies and that the traditional analytical framework that saw rural areas through an agricultural perspective is out of date (Roberts 2002). Nowadays rural areas are more diverse than they were in the past and the divide between rural and urban has become less clear (ibid). Indeed, some rural areas are now less disadvantaged than their urban counterparts. This diversity in rural areas in Europe is reflected in the range of challenges that they face. For some areas, these challenges include restructuring of the agricultural sector, remoteness and poor service provision. For others, especially those near urban centres, population influx and pressure on the natural environment are key concerns (EC 2003). Society's view of rural areas has also changed. With increased public interest in the environment and the emphasis moving from food quantity to food quality, the countryside is considered in many countries as a source of environmental goods rather than a place solely for food production (Roberts 2002).

Forests are a key part of the natural resources of rural areas. In tandem with the changing view of the role of rural areas, society's view of the functions of forests has also changed. For much of the early part of the last century, the 'industrial' timber-production model of forests dominated. However today, the market, which is driven by an increasingly urbanised society, demands a broad range of functions from forests, including functions for the benefit of industry, recreation, housing, nature conservation and the environment. Consequently, nearly all European countries are now committed to sustainable, multiple-use forest management policies (Jeanrenaud 2001).

The changes in the definition of rural development and in the functions of forestry have presented challenges to those attempting to quantify the contribution of forestry to rural development. In the past, this was a relatively simple task. The production-oriented focus of forest management, coupled with the fact that rural development was considered synonymous with economic development, meant that most assessments were limited to counting the number of jobs created and to assessing the income generated. Socio-cultural, political or environmental impacts were rarely estimated or monitored (Kennedy et al. 2001). Such an approach is no longer acceptable. Slee et al. (2004) indicate that the multifunctionality of forests requires that all the multifunctional outputs should be assessed if the aim is to appraise the overall contribution of forestry to the economy. Thus there is a need to investigate not only the economic benefits, but to consider how local communities interpret the meaning of rural quality, how they conceive the desired future of their area and how they perceive forestry as part of their social and physical environment (Wiersum and Elands 2002).

Much progress has been made in recent years in developing techniques that can be used to measure the various ways forestry can contribute to rural development. There are well-established methods available to assess the economic impacts of forestry including cost-benefit analysis and input-output analysis. More recently tools have been developed to quantify the non-market benefits and costs of forestry. However, an area that has received less attention from researchers has been the social impact of forestry. Yet, as Slee et al. (2004) outline, forests may generate social values or be connected with people's lives in ways that contribute to or deduct from social well-being. Typically studies investigating the impact of forestry on rural development have not measured the social impact or limited the assessment to the employment generated. This was partly due to the earlier over-riding emphasis placed on the economic aspects of forestry, but the lack of suitable assessment techniques was also a critical factor. However, both these explanations are no longer valid. As already highlighted, the acceptance of the multifunctionality of forestry requires that the broad range of impacts is assessed, while developments in social impact assessment now mean that appropriate techniques are available. Most commonly social impacts are assessed using a combination of qualitative and quantitative data collection methods. Triangulation is often used to validate the findings (Guion 2002). Data triangulation involves the use of different sources of data in the study. Typically, this involves including all relevant stakeholder groups and interviewing a comparable number of people in each group. Methodological triangulation uses multiple qualitative and/or quantitative methods. Triangulation is achieved when outcomes are agreed by all stakeholder groups and/or when the results of the different methods used agree. Triangulation methods have been used in recent socio–economic studies related to the forest sector. In his socio-economic study of a forest industry host community in Alberta, Parkins (1999) used triangulation methods involving the collection of both statistical information (i.e. census data) and qualitative data to assess two common social indicators of forestry: employment and migration. The collection of qualitative data involved primary narrative information (i.e. interviews) and consultation of local secondary sources (i.e. local newspapers, etc.). Triangulation methods were also used in two recent European projects which quantified the role of forestry in rural development in Europe. The Multifor project (Wiersum and Elands 2002) studied the potential role of forestry in rural areas in nine European countries. A methodology based on triangulation was also used by the Forward project (Hyttinen et al. 2002).

The history of research on forestry and rural development in Ireland is similar to many countries in Europe. Studies using cost-benefit analysis (CBA) (Clinch 1999) or input-output analysis (Ni Dhubhain & Gardiner 1994) have quantified the economic contribution of forestry. However, in neither of these reports were the social impacts of forestry assessed. To address this deficit a study commenced in 2002 to determine the social and economic impacts of forestry on the national and local economies. Three case study areas were chosen to represent the local economies. Each case study was defined as the area within a 20-miles radius of the centre of the case study (i.e. 1,256 square miles/3,254 km^2). Shillelagh, Co. Wicklow, Arigna, Co. Roscommon, and Newmarket, Co. Cork were the geographic centres of the three case study areas. The Shillelagh case study area had a mature forest cover with some second rotation forests present. The Arigna case study area had a middle-aged forest cover, while the final case study area, Newmarket, Co. Cork, had a young forest cover. This paper reports on the social impact assessment study in Newmarket.

Material and methods

Both methodological and data triangulation methods were used in the social impact assessment study in Newmarket. Methodological triangulation was made feasible through the use of a number of qualitative and quantitative data collection methods. Semi-structured interviews were held with stakeholders while other data sources were accessed including censuses and newspapers. In order to achieve data triangulation respondents from a number of stakeholder groups were interviewed, including:

- Producers: people deriving their living from the land (e.g. farmers and foresters);
- Consumers: people living in or visiting the area but not deriving their incomes from the land (e.g. community members and visitors);
- Decision makers: people involved in public policy and lobbying (e.g. councillors, officers from administrations, local group representatives, NGOs, etc.).
- A total of 35 persons were interviewed with approximately one third in each stakeholder group. The initial identification of respondents was done using key informants from organisations such as the Agriculture and Food Development Board, County Councils and locally based rural development organisations. This initial group of respondents then guided the interviewer to further respondents. During the course of the interview the following issues were discussed:
- What is the perception of the respondent of the rural environment she/he lives in?
- What role does forestry play in it?
- How can this role be improved?

Unless people objected to it, each interview was recorded and subsequently transcribed.

Results

The Newmarket case study area is located in the southwest of Ireland. The area, although essentially rural, is quite close to Cork city with the southeast border no more than ten miles from the city. The population in the case study area declined by 8.6% between 1946 and 2002. Just over 13% of the area is afforested (34:66 private/public) with much of the forest cover less than 20 years of age. Similar to the trend in the rest of the country, the forest estate is dominated by Sitka spruce (87%), an exotic conifer which has an average growth rate of 18 m3ha-1an-1 throughout much of the country.

Afforestation in this area has attracted some criticism since the early 1990's when the Coillte (The Irish Forestry Board) estate started to expand. Increased demand for land for afforestation resulted in an increase in land prices. Farmers who wished to extend their holdings couldn't afford to do so and forestry was then perceived as a depopulating agent (Crowley 1998). In 1993, an action group, based in the area, started to challenge what they called the 'blanket afforestation' of the area and its associated ecological and social impacts. More recently a national newspaper highlighted another dispute relating to afforestation in Coolea, at the southern border of the case study area. In this case, a local resident group objected to the afforestation of a 33 ha site by Coillte in partnership with a local farmer, on the basis of the absence of consultation with the local community.

The interviews with the stakeholders showed that the opposition to forestry that had been highlighted in local and national newspapers (see above) continued to prevail. The interviews revealed that this opposition was based on a number of factors including the limited positive impact of forestry on the local community as well as the perceived negative impacts of forests on the environment. Concerns were also expressed about the lack of consultation with the local community regarding afforestation in the area. In examining these perceptions, statements made by some of those interviewed are included for illustration purposes.

Those interviewed considered that forestry had not benefited local communities in the way it was meant to:

> "I don't think forestry has benefited the community the way it could have. It benefits certain individuals, certain companies, certain groups but in a very narrow way."

While the employment that forestry had generated in the past was acknowledged, forestry was no longer recognised as a significant employer:

> "Going back 20 years ago, when Coillte more or less started forestry development, I remember 22 people from this parish working for Coillte. For all the forestry here now there is only one full-time job and two part-time jobs."

Foresters in the area commented on the fact that people don't always make the connection between forestry and jobs that are created downstream and in allied sectors:

> "People don't make the link between forestry and employment. The main source of employment in the area is the processing industry, mainly in the south of the county. Also there are a lot of truck drivers employed in the area."

The extent to which the public use forests for amenity and recreation is considered a social indicator of forestry (Forest Service, 2000). However, only a small number of those interviewed referred to the amenity value of forests in the area and those that did considered it to be negligible:

> "The Sitka spruce forests are of no interest as amenity woodland for people…… would be more acceptable for people if they had amenity woodlands with broad-leaved species or with a mixture."

Foresters in the area agreed that the amenity value of local forests was low:

> "Forests in the area have a very limited use for amenity; the main objective so far has been the timber production. But the situation now is changing and we try to develop opportunities such as picnic areas and marked roads. We are also developing horse riding and long distance trails and we encourage a mixture with broadleaves in new afforestation sites."

Dissatisfaction was expressed with the planning and consultation process that pertains to forestry development. Currently an environmental impact assessment much be completed before afforestation developments that are in excess of 50 ha are approved by the Forest Service. Those interviewed felt that smaller developments should also be required to have some form of EIA completed as they too have impacts for people living nearby. The current public consultation process for all forestry developments was also considered unsatisfactory. This process essentially involves advertisements being placed in local newspapers indicating that a proposal to afforest land in the area has been received by the Forest Service. In general, the public wanted greater consultation on afforestation proposals. Some foresters interviewed agreed with this sentiment and even took it a step further:

> "The lack of communication with locals has lead to negative perceptions from the general public. The forestry sector should be supported by foresters through, for example, their involvement in environmental education and through direct consultation with the public."

Concerns about the negative impact of forests on aspects of the environment such as the landscape and the quality of watercourses were expressed. There was a perception among many of those interviewed that forestry does not belong in the traditional Irish landscape. However forestry in this context almost always referred to commercial Sitka spruce plantations:

> "The open landscape is the real Irish landscape. The presence of forestry in this landscape doesn't make it attractive anymore for the tourists and the visitors."

The establishment of forests also led to feelings of isolation among some of those interviewed:

> "The open Irish landscape is the reflection of the Irish personality…. Traditionally the landscape was open and people could see each other's houses and farms. Now the view is blocked by forests and people feel displaced by trees."

Forestry was also perceived to have negative impacts on watercourses. The main river system present in the area is renowned for fishing and is an important natural asset that the local community values:

> "We have floodings in the area that are more frequent than in the past. Forests were established essentially on uplands and on bog soils. These soils don't operate anymore as a water regulator …We have a problem with the acidification process."

Those interviewed were asked about the future role of forestry in the area. In general the view was expressed that more forests would be welcome but not those of the type that had been planted in the past:

> "We will have no objection to the normal forests: the oak, the ash, and the broadleaves. We will have no difficulties with that. But we have difficulties with this massive growth of Sitka spruce."

Even though the farmers interviewed often expressed reserved, if not negative, opinions towards forestry, there was recognition that afforestation schemes offered farmers the possibility to increase farm incomes. This was particularly true for those operating hill farms and/or small-scale farms:

> "When afforestation programmes started they offered a means to farmers to complete their incomes and to obtain revenue from lands that were not suitable for farming. It was especially appropriate in the north of the county where farming has always been small-scale and with low incomes."

However, the farmers surveyed felt strongly that forests should be restricted to marginal lands that can't be used for farming.

Among some of the farmers interviewed who had afforested part of their land, concern was expressed about the future of their plantations. These concerns were mainly to do with the value of the timber:

> "Back 10 years ago afforestation was the only viable option but I won't do it anymore. The outlook for Sitka spruce is very low and there is very little added-value to the final product …The timber produced here is of very low quality. It is cheaper to import wood from Eastern Europe than to harvest local forests."

However other farmers still saw forestry as a suitable alternative to farming and were hoping for the development of a market for small diameter timber:

> "There are some prospects for the market of small diameter woods. The Co-op intends to set up a project to use firewood as a means for generating power."

Discussion

It is clear from the results of this study that the social impacts of forestry have, to date, been negative in the Newmarket case study area. Forestry was not perceived to 'fit' well into the social and physical environment of the area and was considered to have contributed little in terms of employment and amenity while impacting negatively on the environment.

In the past the key impact of forestry on rural communities was considered to be employment generation. However, in the Newmarket area, despite almost 13% of the area being afforested in the last 25 years, those interviewed considered the employment levels associated with forestry to be low. There may a number of valid reasons for this including the increased mechanisation of forest operations coupled with the mobility of the forest work force. Also much of the employment associated with forests occurs at the harvesting stage and in the processing of the timber output a point raised by the foresters interviewed. However, given the age-class structure of the forests in Newmarket these activities have not occurred to date.

A key element of sustainable forest management is community participation and consultation with stakeholder groups. Those interviewed in the area did not believe they had been adequately consulted when afforestation was about to take place. Even the foresters surveyed recognised that greater consultation with the public is required. However, it is not clear whether consultation meant the same thing to both groups. As was evident from some of their comments, the general public, including farmers, wanted to influence which lands should be afforested and with what species. From the foresters' perspective consultation may have meant greater dialogue with the local community as to the choice of species planted but without giving the local community the power of veto. Nevertheless in other parts of the country improved dialogue between local communities and foresters has led to a decline in conflicts between the two groups (Ni Dhubhain et al. 2006). Similarly studies from other countries have revealed that a more collaborative and participatory approach to forestry decision-making has resolved many conflicts (Daniels and Walker 2001).

The rate of afforestation within the area has been quite dramatic. This, coupled with the initial reliance on one coniferous species with a rapid growth rate, has undoubtedly had a dramatic impact on the landscape in the area. Both the producers and consumers interviewed clearly considered this impact to be negative. Much of this negativity was associated with the species planted, namely Sitka spruce. However, there were sound silvicultural reasons for choosing this species given that the sites planted initially were in upland areas where the species had already proven capable of good growth rates. Furthermore, the emphasis in government forest policy was the financial support of afforestation for the purposes of timber production. Notwithstanding the silvicultural reasons for the choice of species, the lack of species diversity inevitably has led to a rather bland landscape. More recently, developments worldwide and in Ireland in relation to sustainable forest management and the increasing concerns about biodiversity, mean that although the Forest Service continues to emphasise the timber production function of forests, it is now mandatory for afforestation developments to comply with a set of environmental guidelines relating, inter alia, to the landscape. Furthermore, since the 1990s it has been government policy to increase the broadleaf component of the national afforestation programme to 30% (Department of Agriculture, Food and Forestry 1996). Thus monocultural coniferous forests that comprise much of the forests in the Newmarket area will not be planted in the future.

Forests as a land-use are dynamic and their social impacts change as they change. The social impacts of forestry in the Newmarket area have been mostly negative so far. However, results from the other case study areas show that the age and diversity of forests have a major bearing on their social impacts (Ni Dhubhain et al. 2006). It is likely that, as the forests in Newmarket mature and younger forests are established with a greater diversity of species, more positive social impacts will emerge. It would be very interesting to test this hypothesis in ten years' time.

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2. Ecosystems

2.1 Restoration of birch and willow woodland on eroded areas

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Abstract

Birch and willows are useful for rehabilitation of degraded land in Iceland as they are often early colonizers in succession and key species in ecosystem development. Restoration of birch and willow woodland or shrubland on eroded areas may have several different objectives, including restoration of ecosystem function and biodiversity, carbon sequestration and improved options for future land use. Reclamation in order to reduce soil erosion and restore ecosystem function is often a prerequisite for establishment of birch and willows on severely degraded land. Birch can be established by planting of seedlings or direct seeding, but planting of cuttings is the most common method for propagation of the willows. Both birch and willow species have a great potential for natural regeneration and this can be utilized in restoration work by establishing tree and shrub 'islands' that will serve as seed sources for further colonization. Strategies for restoration of birch and willow woodlands and shrublands are presented in relation to a large-scale restoration project that is now being planned near the Mt Hekla volcano in South Iceland.

Keywords: Betula pubescens, birch woodland, erosion, restoration, *Salix lanata*, *Salix phylicifolia*, willows.

Introduction

Land degradation and soil erosion have changed Icelandic ecosystems since human settlement. As a result, extensive areas are now deserts with shallow and poor soils, low biodiversity, limited function and unstable surfaces with active erosion (Arnalds et al. 2001). Natural succession on the eroded areas is usually slow and restoration of ecosystem structure and function is limited by many factors such as erosion, poor soils and lack of propagules (Magnusson 1997, Gretarsdottir et al. 2004).

Birch (*Betula pubescens*) and willows (especially *Salix phylicifolia* and *S. lananta*) play a key role in many Icelandic ecosystems. Birch is the only native species that formed woodlands in Iceland during the Holocene, but the current extent of birch woodlands is only a fraction of the former distribution. The willows *S. phylicfolia* and *S. lanata* are very common in Iceland. They often form the shrub layer in birch woodlands (Aradottir et al. 2001) and are found in numerous other vegetation types, both in dryland and wetland vegetation. Willow shrublands were more important previously than they are now, especially at higher elevations and in highland areas where they can form a continuous shrub layer. Birch and willows are among early colonizers in primary succession in Iceland and play an important role in ecosystem development when they are present.

The role of birch in revegetation and reclamation projects is increasing. The use of birch can fulfill several different objectives, including the restoration of native woodlands, restoration of ecosystem structure and function, for soil and water conservation, sequestration of carbon, restoration and preservation of biodiversity, as well as rehabilitation of land for different uses, such as recreation or grazing (Aradottir and Eysteinsson 2005).

A large-scale restoration project called "Hekluskógar" (Hekla woodlands) is now underway in S Iceland. The goal of this project is to reduce the potential damage caused by tephra or ash from eruptions in Hekla by restoring birch and willow woodland and shrubland on extensive areas around the volcano. This project will be used here as an example of how birch and willows are used in restoration projects in Iceland.

Hekluskógar: woodland restoration near an active volcano

Tephra (volcanic ash) deposited during eruptions from Mt Hekla is easily moved by wind and water. This can cause extensive disturbance and damage to ecosystems and properties near the volcano and also at some distance due to eolian redistribution of the tephra materials. In Iceland there are striking examples of widespread erosion events following volcanic eruptions (Arnalds 2000); thus it is important to apply some preventive measures. This is most effectively done by establishing trees and shrubs on the areas that might be affected, thus increasing surface roughness and reducing wind speed, which results in reduced probability of eolian movement of tephra.

Stakeholders that were interested in promoting the Hekluskógar project appointed a Steering Committee in April 2005 to define the project and oversee the planning process, disseminate information about the project, obtain funding, etc. This group included representatives from the local landowners, local afforestation societies, the Soil Conservation Service and the Forest Service of Iceland, the South Iceland afforestation project and the Afforestation Fund of Iceland. Several teams of managers, extension specialists and scientists have been working together on the planning and preparation for Hekluskógar in co-operation with the Steering Committee (HPSC 2005).

The total size of the proposed Hekluskógar area is between 900 and 1000 km^2, or nearly 1% of Iceland. A decision was made by the stakeholders to focus on the native birch and willow species in the project. This decision was taken for several practical reasons, besides representing the restoration of historical woodlands of the area. These species have tolerated tephra deposition in the past and they play a key role in restoration of function and biodiversity of eroded areas (Oddsdottir 2002, Oradottir 2002, Oddsdottir unpublished data). Last, but not least, birch and willows have a capacity for considerable natural regeneration (Aradottir 1991, Aradottir et al. 1999), which is an important quality when working with such a large area where the planting of every tree would be virtually impossible.

The initial step in the preparation for Hekluskógar was an assessment of the existing reclamation/restoration knowledge base and the conditions of the area. The proposed methodology is based on a number of research projects as well as reclamation and reforestation experience, much of it from within the area in question. Remote sensing, ground mapping and GIS technology are used as a basis for spatial planning. The most urgent knowledge gaps are also being identified and new research is planned.

Conditions in the Hekluskógar area

The upper limits of Hekluskógar on the slopes of the Mt Hekla volcano are set at 600 m elevation. This is based on the assumption that willow shrubland can extend up to at least 600 m, birch woodland and shrubland can be expected to extend up to at least 400 m, and birch forest up to 300 m. However, there are recent lava fields, archeological remnants and nature conservation sites within the Hekluskógar area where restoration efforts will be restricted. Areas that are now used as grazing commons for the local communities initially will also be excluded from the restoration efforts. Furthermore, on farms and other privately owned land within the area, participation in the project is subject to compatibility with other land uses and priorities set by the landowners. After all this has been taken into account, more than 600 km^2 are estimated to be included in the initial reclamation and afforestation efforts of the Hekluskógar project (HPSC 2005).

Erosion is widespread in the Hekluskógar area and more than half of it has active or very active erosion and sparse vegetation cover ($<33\%$, often <5%; Figure 1). Eroded areas have soils with low nutrient levels and low water holding capacity and their surface is unstable due to wind and water erosion, as well as intensive cryoturbation in winter. Other areas have more stable surfaces and more favorable conditions for plant establishment and growth. Birch woodlands are found at some locations, in most cases remnants of extensive woodlands that once covered most of the lower lying areas. The woodland remnants together with written accounts of woodland utilization and degradation history indicate a very different status of the natural resources near Mt Hekla than is evident today.

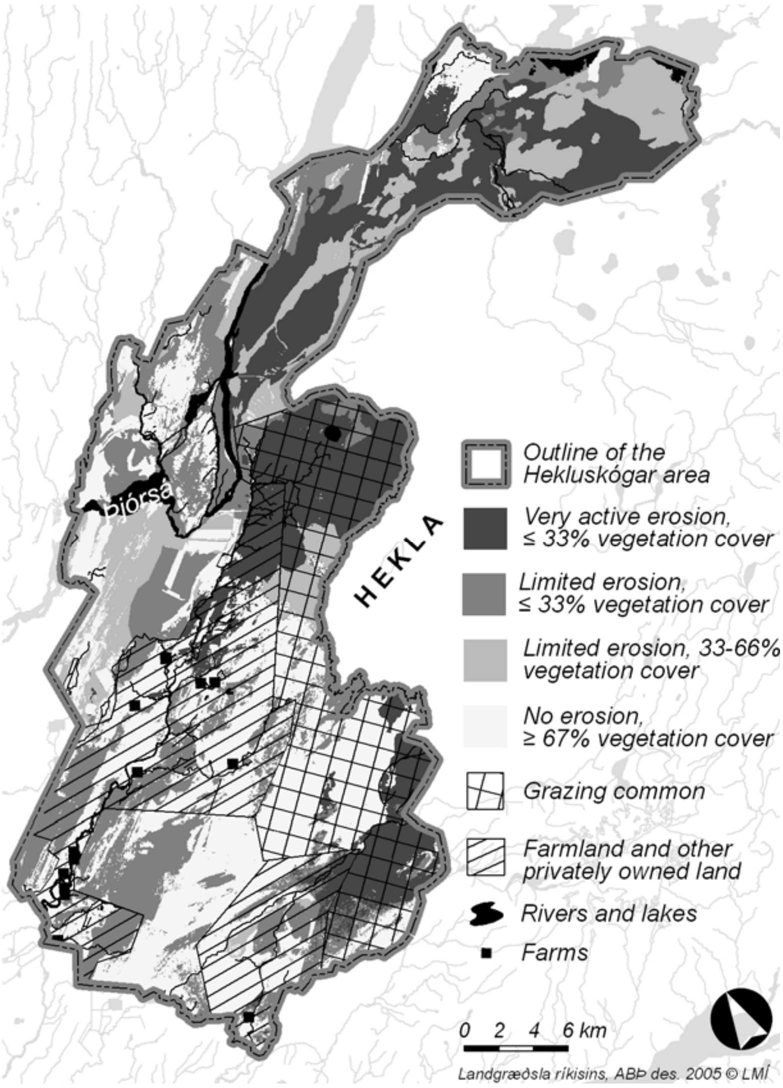

Figure 1. Erosion and vegetation cover classes in the Hekluskógar area. The 'no erosion, ≥ 67% vegetation cover' class includes both land that has not been eroded and revegetated land. Grazing commons will not be included in the initial restoration efforts of Hekluskógar. On farmland and other privately owned land within the area, restoration of birch woodland is subject to compatibility with other land uses and priorities set by the

landowners (Figure prepared by Arna B. Thorsteinsdottir, Icelandic Soil Conservation Service).

Restoration methods

Methods used for restoration need to be applicable for specific conditions at each site. Areas that have more or less fully functional ecological processes may only need management changes or establishment of seed sources of desired species in order to achieve desired restoration goals. Areas that have crossed transition thresholds often require modification of the physical and chemical environment in order to restore their function (e.g. Whisenant 1999). Extensive areas in Hekluskógar have very limited ecosystem functioning and autogenic recovery is hampered by a suite of factors including soil erosion, frost heaving, limited water retention and severe nutrient limitation, as well as lack of propagules, appropriate symbionts or important soil organisms (e.g. Arnalds and Kimble 2001, Elmarsdottir et al. 2003, Enkhtuya et al. 2003). Revegetation by common agronomic methods, such as fertilization and seeding of grasses can help to bring the system over some of these thresholds and stimulate vegetation succession and ecosystem development (Elmarsdottir et al. 2003, Gretarsdottir et al. 2004, Aradottir and Halldorsson 2004). Striking examples of birch and willow colonization in revegetated land are found in the Hekluskógar area. However, these are of limited extent and for most of the area, colonization of these species is limited by lack of propagules and 'safe sites' for seedling establishment.

The probability of seedling establishment for birch and willows is greatest in stable but open sites, especially those characterized by biological soil crusts or thin moss layer, but colonization is limited in dense vegetation or on unstable bare ground (Aradottir 1991, Aradottir et al 1999). Recent studies have demonstrated that biological soil crust can be formed within a few years of initial revegetation efforts on eroded sites (Elmarsdottir et al. 2003, Aradottir and Halldorsson 2004). Simple revegetation treatments may therefore be sufficient to create suitable conditions for establishment of birch and willows on unstable eroded soils. However, this will not ensure colonization unless there is abundant seed rain.

Birch and willow seed are predominantly dispersed by wind and, and seed rain as well as seedling establishment decreases rapidly with increased distance from the seed source (e.g. Aradottir 1991, Gage and Cooper 2005). The colonization pattern of birch has also been shown to be strongly directional, with the width of the regeneration belt being greatest leeward of strong, dry winds (Aradottir et al. 1997). A strategy mimicking observed patterns of stand development has been suggested, involving establishment of tree 'islands' in selected locations across landscapes that could subsequently serve as seed sources for surrounding areas (Aradottir 1991).

There has been a number of studies on the establishment of birch by planting (summarized by Aradottir and Eysteinsson 2005), some in the Hekluskógar area. The most recent include the planting of native legumes as nurse species (M. H. Johannsson, unpublished data) and inoculation by appropriate mychorriza (Enkhtuya et al. 2003), which would reduce the need for continued fertilization. A number of studies on the propagation of the native willows have made these species more attractive to use (Svavarsdottir 2006). Direct planting of fresh cuttings is a viable method that makes the use of local material easy, as both collection and planting can take place during the same day or trip. When planting poorly vegetated sites, mulching and fertilization will greatly improve survival and plant growth (Svavarsdottir 2006). Direct seeding of birch can be successful, given that seed is abundant and easy to collect and that the seeded areas have sufficient density of safe sites (Aradottir 1991, Magnusson 1997). Direct seeding of willows is more problematic because the seed has no dormancy and is difficult to handle, but studies have shown that it is possible to store the seed by freezing (see Svavarsdottir 2006).

Strategies

It is not feasible to restore birch and willow woodlands in Hekluskógar by planting the whole area because of its large extent. Instead, the potential of birch and willows for natural colonization will be utilized by planting a large number of birch and willow 'islands' that will become sources of seed rain. Much of the area will also be subject to reclamation treatments, in order to reduce erosion, restore function and create conditions suitable for establishment of birch, willows and other native plant species (Table 1).

Lymegrass (*Leymus areanarius*) will be seeded in part of the area characterized by very active erosion to stabilize drifting sand and halt erosion. Adjacent areas will be fertilized to take advantage of seed rain from the lymegrass patches. It is estimated that these areas will be stabile and ready for planting of birch and willows in 8–10 years. Areas with active erosion will be seeded with grasses (especially *Festuca* spp. and *Poa pratensis*) and/or fertilized to stabilize the soil and improve conditions for seedling establishment. It is estimated that these areas will be ready for planting of shrubs and trees in 2–3 years. Areas with limited or no erosion are more or less ready for planting.

The birch and willow islands will be planted in areas with an abundance of safe sites for seedling establishment or where measures will be taken to increase availability of safe sites. By concentrating resources within these islands, instead of planting larger areas, more steps can be taken to ensure success, such as planting native legumes within the islands to promote sustained growth of the trees and shrubs, inoculation of the trees with mychorriza, etc.

Table 1. Estimated area of different erosion and vegetation cover classes included in the initial reclamation and afforestation efforts of the Hekluskógar project, and a summary of proposed measures for restoration of birch and willow woodland in this area (source HPSC 2005).

Erosion class	Veg. cover	Est. area (km^2)	Reclamation measures	Afforestation measures
Very active erosion	≤ 33%	150	~50% seeded with *Elymus areanius*; all the area fertilized 3–4 times	Planting of islands with birch, willows and native legumes, 8–10 yrs
Some erosion	≤ 33%	190	~75% seeded with *Poa* and *Festuca*, fertilized 3 times	Planting of islands with birch, willows and native legumes
Limited erosion	34–66%	115	~70% fertilized 3 times	Planting of islands with birch, willows and native legumes
No erosion	≥ 67%	170	No revegetation needed	Planting of islands with birch and/or willows

Projects such as Hekluskógar really test our understanding of processes involved in ecosystem development and restoration. It is planned to monitor and evaluate the restoration progress as a basis for adaptive management and research opportunities within the project will be utilized. Thus, we envision that the Hekluskógar project will have a role in strengthening the conceptual framework for restoration, as well as resulting in the restoration of important ecosystems and their services.

Acknowledgements

I want to acknowledge the contribution of colleagues and co-workers in the steering committee and the working groups for the Hekluskógar project to the ideas and strategies for the project that are presented here. Figure 1 and the information in Table 1 are based on the work of the Hekluskógar planning and GIS working group: Arna Björk Thorsteinsdottir (chair), Björgvin Eggertsson, Bödvar Gudmundsson, Gardar Thorfinnsson, Hreinn Óskarsson, Magnús H. Johannsson and Ulfur Óskarsson.

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2.2 Afforestation effects on decomposition and vegetation in Iceland

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Abstract

The aim of this study was to investigate variation in decomposition and vegetation due to afforestation. The ICEWOODS sites containing stands of different tree species and age in the western (Skorradalur) and eastern (Hallormsstaður) parts of Iceland were investigated during the summer of 2004. These stands were compared with treeless pastures. The planted stands represent chronosequences, i.e., different age classes within each tree species were studied.

Decomposition was studied by a cotton strip assay. Cotton strip decomposition increased with incubation time and decreased with soil depth. The tree species can be ranked according to increasing decomposition in the following series: lodgepole pine < Sitka spruce< Siberian larch < mountain birch. In general, decomposition decreased with increasing age of the stands.

Ordination of the vegetation data revealed a clear succession from open pasture toward older tree stands due to gradual loss of light-demanding species and increased abundance of shade-tolerant species. The succession in birch stands followed a different pattern from the coniferous tree stands. Within the conifers, species richness was highest in larch and lowest in Sitka spruce.

Keywords: Afforestation, decomposition, cotton strip assay, vegetation

Introduction

Afforestation influences ecosystem processes and biodiversity in different ways. This work (see also Arneberg 2005) is a comparison of decomposition in planted stands of the tree species lodgepole pine (*Pinus contorta*), Sitka spruce (*Picea sitchensis*), Siberian larch (*Larix sibirica*), and mountain birch (*Betula pubescens*). Within each species, stands of different ages (chronosequences) were studied with respect to decomposition and field vegetation. The stands were also compared to open pasture vegetation.

Materials and methods

Field work was carried out during the summer of 2004 the in the western (Skorradalur) and eastern (Hallormsstaður) parts of Iceland, within sites used in the ICEWOOD project (Figure 1). The forest stands of lodgepole pine (*Pinus contorta*), Sitka spruce (*Picea sitchensis*), Siberian larch (*Larix sibirica*) and mountain birch (*Betula pubescens*) were compared with treeless pastures. The planted stands represent chronosequences, i.e., different age classes within each tree species were studied.

Cotton strip assays (Correll et al. 1997) were used to evaluate variation in decomposition among the different tree species, according to standardised procedures (Sagar 1988). Within each stand and in each area of treeless pasture, 10 cotton strips were inserted vertically into the soil. Five strips were left for 5 weeks and five for 10 weeks. After the predetermined incubation time, the cotton strips were collected, and the tensile strength of the cotton strip was determined by means of standard equipment and procedures (British Standard 1986, Figure 2). Tensile strength (the force needed to tear the cotton strip) was measured (in Newton) for the cotton strips in 3 different depths; 0–5, 5–10 and 10–15 cm. The tensile strength is used as a relative measure of the decomposition which has occurred during the experiment.

Plots 1 m^2 in area were established around each cotton strip for analysis of the vegetation. Here all plant species and their cover (%) were recorded. The vegetation data were analysed by ordination (DCA, Hill 1979) in order to detect variation among the tree species and the ages of the stands.

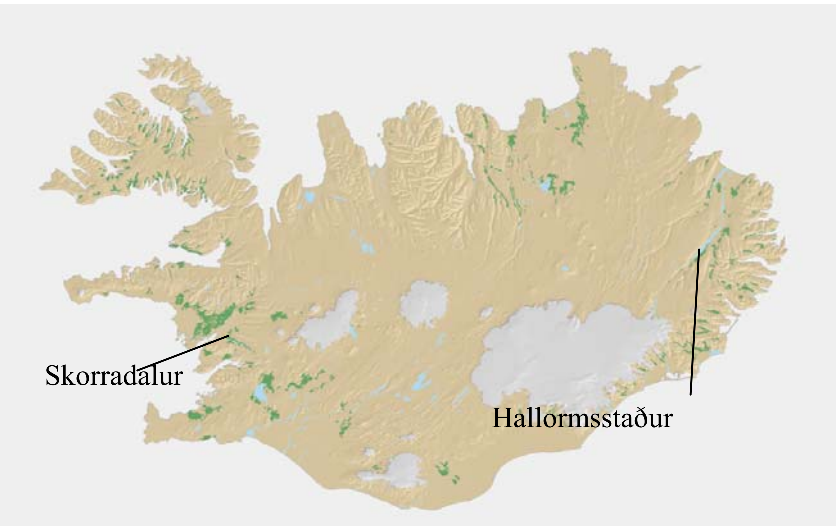

Figure 1. Geographical position of the investigated sites on Iceland.

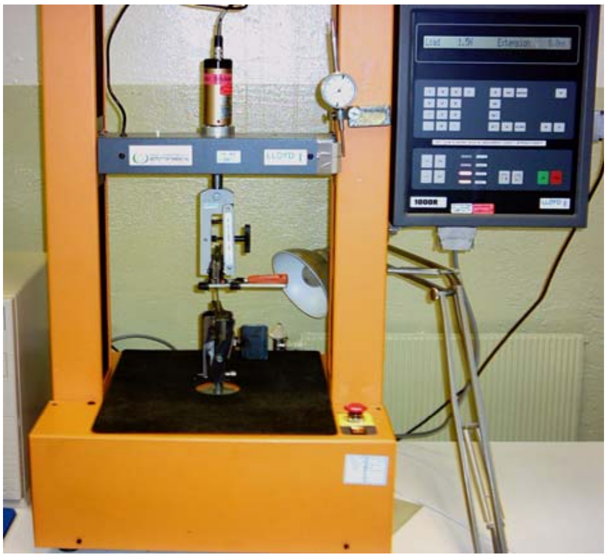

Figure 2. Machine (Lloyd L-1000 R) for measuring tensile strength of the cotton strips.

Results and discussion

Decomposition increases with incubation time and it decreases with depth. In the figures only results from 2 months' duration and the upper 10 cm of the profile are presented. Among the different coniferous tree species the decomposition rates were highest (i.e. the tensile strengths lowest) in Siberian larch (L) stands and lowest in lodgepole pine (F) stands (Figure 3). Possible explanations for the differences were the variation in litter quality among the tree species and microclimatic changes due to canopy structure.

There was a significant increase in tensile strength with increasing age of the stands within both Sitka spruce (Figure 4) and lodgepole pine. The reason was probably that the older stands had a higher canopy density. Canopy density affects light, temperature and humidity in the forest floor and in turn changes conditions for the decomposer microorganisms, with the result that decomposition decreases. However, if the forest then is thinned, which was the case for the oldest Sitka spruce stand (cf. Figure 4), the decomposition conditions seemed to improve.

Ordination analysis (DCA) of the vegetation data revealed a gradient from treeless pastures to closed forests along the first axis (Figure 5). The data for Sitka spruce and lodgepole pine stands especially differed markedly from data for the pastures.

In figure 5, only the plots from the chronosequences from mountain birch (HB1,HB2) and Siberian larch (HL1-HL5) at Hallormsstaður are shown. The changes in forest floor vegetation relative to the open pasture (HM) situation increased with the age of the plantations, but the succession was different in birch and larch stands. In larch stands the mean number of species per plot varied from 12.4 in the youngest stand to 5.3

in HL4 (in comparison, 14.5 species were found per plot in the open pasture). In the oldest stand (HL5), the species richness increased again, to 8.2 species. Also in the birch stands, species number was reduced. Reduced light availability was the most important factor for these vegetation changes. Typically light-demanding species such as *Dryas octopetala* and *Bistorta vivipara* are common in open pasture, while shade tolerant species (e.g. *Rubus saxatilis*) become more abundant with increasing age of the stands.

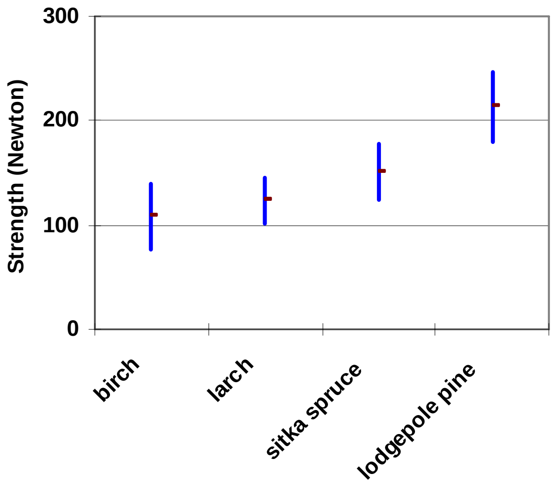

Figure 3. Decomposition rates in stands of different tree species, measured as tensile strengths in a cotton strip assay. Vertical bars represent 95% confidence intervals for the means. Figure

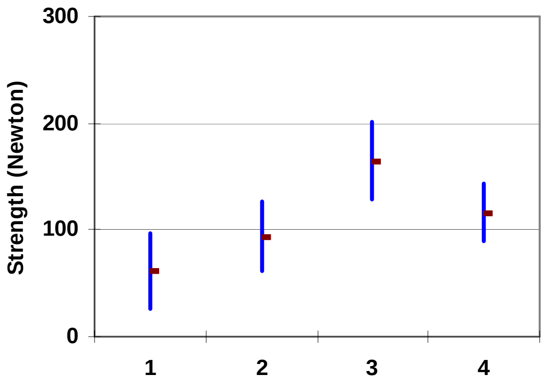

Figure 4. Decomposition rates in stands of Sitka spruce (Picea sitchensis) of different ages (1–4). Vertical bars represent 95% confidence intervals for the means.

Conclusions

A clear difference in decomposition rate among treeless pastures and stands of different tree species and age was noted in this research. The main tree species used for afforestation on Iceland can therefore be ranked according to increasing decomposition:

Lodgepole pine < Sitka spruce < Siberian larch < Mountain birch.

Afforestation influenced the field layer vegetation by reducing light availability and thus excluding light-demanding species. In future afforestation activities the different properties of tree species should be taken into consideration in order to choose the most ecologically favourable species.

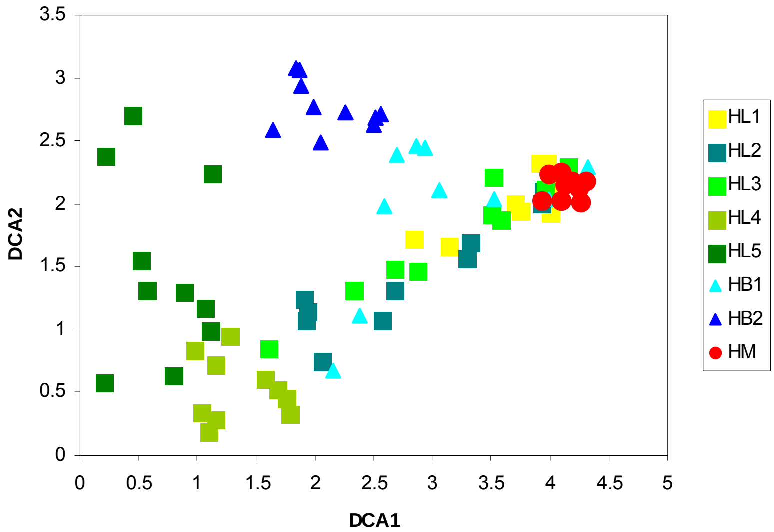

Figure 5. Ordination analysis of vegetation data from tree stands of different ages. Only plots from Siberian larch and mountain birch stands at Hallormsstadur are shown. Increasing figures represent increasing age. HL: larch stands, HB: birch stands, HM: open pasture.

Our results indicate that the cotton strip assay is a promising method for detecting differences in decomposition between different treatments in boreal forest ecosystems. The low cost is also an important advantage of the method.

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2.3 Adapting the ForSAFE model to simulate changes in the ground vegetation after afforestation in Iceland: A feasibility study

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Abstract

The ForSAFE-VEG model was modified to reconstruct the effects of afforesting a formerly open grazing site to a Siberian larch forest. The model was modified by including a simplified growth module for the ground vegetation. The model predictions for standing forest wood biomass and soil chemistry compare well with field measurements. However, the model reconstruction of the soil organic matter does not fit with the observations. The model predicted a reduction in the mosses occupying the site, an increase in the berries and lichens, an establishment of grasses, and the establishment of other woody perennials represented by *Salix lanata*. The present work suggests that the ForSAVE-VEG model is applicable to Icelandic conditions, but that more work is needed before the model can accurately reconstruct the composition of the soil organic matter.

Introduction

Contemporary social requirements have driven a shift from traditional land uses, such as family farming, to new forms of land productivity. With the refinement of agricultural techniques, the increasing volume of traded goods, and the rise of new environmental challenges, many developed countries are dedicating more land for social and environmental services. These services range from recreational activities or soil preservation on a small scale, to larger issues such as carbon sequestration to mitigate the release of carbon dioxide in the atmosphere from human activities. Whatever the reasons, a large afforestation movement is taking place. This is also the case for Iceland. While the debate on the relevance of afforestation in Iceland is still ongoing, efforts to investigate the success of forest plantations have already started. The Affornord Conference on Effects of Afforestation on Ecosystems, Landscape & Rural Development (Affornord, 2005) in Reykholt put the focus on the ongoing afforestation programs in Iceland and the expected impacts they could have on different sectors. The present work contributes to this discussion from a conceptual and practical perspective. Modifying an existing mechanistic model for changes in forest ecosystems, this work investigates the changes following the afforestation on a grazed site in eastern Iceland.

Theory and method

The ForSAFE-VEG model

ForSAFE (Wallman et al., 2005, Belyazid and Sverdrup, 2005, Belyazid et al., 2005), the part of ForSAFE-VEG which reconstructs a forested ecosystem but ignores the ground vegetation effects was constructed based on the merger of four existing models, namely the soil chemistry model SAFE (Alveteg, 1998), the photosynthesis-evapotranspiration and tree growth model PnET (Aber and Federer, 1992), the soil organic matter decomposition model DECOMP (Walse et al, 1998), and finally the soil hydrological model PULSE (Lindström and Gardelin, 1992). ForSAFE is a mechanistic model which aims at reproducing the biogeochemical cycles of carbon, nutrients and water, originally concerned with forest ecosystems. In a first stage, ForSAFE was extended into ForSAFE-VEG (Sverdrup et al., 2005) by including a ground vegetation module which simulates the composition of the ground vegetation. For the purpose of this study, ForSAFE-VEG has been adapted to include a ground vegetation growth module which is responsible for carbon fixation, nutrient and water uptake and litter production in the absence of a forest. A detailed description of the mechanisms simulated in ForSAFE can be found in Wallman et al. (2005), Belyazid et al. (2005) and Belyazid and Sverdrup (2005), and a detailed description of ForSAFE-VEG can be found in Sverdrup et al. (2005). For a detailed description of the modelling of the ground vegetation composition, please consult Sverdrup et al. (2005). To avoid redundancy, the present paper will only present changes in the model for adaptation to the Icelandic terrestrial ecosystem that was studied (Sigurdsson et al. 2004).

The ground vegetation growth module

A simple ground vegetation growth sub-model was developed to account for the effect of the ground vegetation of the soil carbon, nutrient and water balances. The sub-model calculates yearly biomass growth as a function of soil solution nitrogen and ambient air temperature according to Equation 1.

$$G\_NPP = (0.4 + 0.2 \cdot T - 0.01 \cdot T^2) \cdot (2.54 + 4.91e6 \cdot [N] - 2.22e9 \cdot [N]^2)$$

where G_NPP is the net primary production of the grassy vegetation in g·m-2·a-1, [N] in the nitrogen concentration in the soil solution in kmol·m-3 and T is the ambient air temperature in ºC. Equation 1 is valid with the assumption that water, light and nutrients other than nitrogen are not limiting for growth. This is corrected under the forest canopy by including a light shading term that reduces the GNPP. The model also assumes that all the yearly growth is returned to the soil as litter. The growth is assumed to start with the start of the growing season (in this case we used a degree days sum of 100) and that the litter production takes place at the end of the growing season (degree days sum of 1200).

The Mjóanes site

The study site is situated in eastern Iceland at an elevation of 60–90 m. The site has been closed to grazing and was planted in 1966 with Siberian larch (*Larix sibirica*). Today the site is stocked with a density of 2200 trees per hectare and has not been thinned.

Data requirements for the model simulation

Table 1 presents the set of site specific input data used for the present simulation. The vegetation parameters were selected for Siberian larch, the tree species planted at the site. The mineralogy was derived using the UPPSALA model (Holmqvist, 2004) from a total chemical analysis of three soil samples corresponding to the three defined soil layers. The soil is considered down to a depth of 20 cm. The measured Base Saturation (BS) values were used for calibrating the BS at the start of the simulation. The model requires no further calibration.

Table 2 contains a summary of time dependent inputs. The average yearly precipitation and temperature were derived from measured data for 1996. The radiation data were derived from Swedish and Norwegian sites at latitudes similar to Hallormstadur, and need to be replaced by more accurate data. Deposition values were kept at a constant throughout the simulation. The quality of the deposition data needs to be improved as it is crucial to the soil chemistry at the site.

Preliminary results and discussion

Table 3 shows measured and modelled values of selected variables. The variables shown were selected to indicate the reproduction of the aboveground vegetation, the soil organic matter and the soil solution chemistry. The model closely reproduces the measured value of standing tree wood biomass.

Table 1: Selected site specific parameters used for the ForSAFE-VEG simulation at the Hallormstadur site.

Parameter	Unit	Vegetation parameters		
Slope of photosynthesis response to foliage N%	--	101.9		
Intercept of photosynthesis response to foliage N%	$nmol \cdot g^{-1} \cdot s^{-1}$	106.0		
Foliage retention	year	1.0		
Light half saturation	$\mu mol \cdot m^{-2} \cdot s^{-1}$	200		
Maximum specific leaf weight	$g \cdot m^{-2}$	200		
Water use efficiency as a fraction of VPD	--	10.9		
		Soil parameters per layer		
		1	**2**	**3**
Layer thickness	m	0.05	0.05	0.1
Water holding capacity	$m^3 \cdot m^{-3}$	0.53	0.45	0.38
Wilting point	$m^3 \cdot m^{-3}$	0.16	0.16	0.16
CO_2 pressure	Times ambient	5.0	5.0	20.0
Soil bulk density	$kg \cdot m^{-3}$	500.0	725.0	850.0
Log Gibbsite coeff.	--	6.5	7.5	8.0
Base saturation	%			
CEC	$eq \cdot m^{-2}$	9.0	10.3	22.5
Surface area	$m^2 \cdot m^{-3} \cdot 10^6$	0.7	1	1.1
Mineralogy	%			
K-feldspar		5.6	7.6	3.6
Plagioclase		10.0	10.8	9.1
Volcanic Glass Poor		0.0	0.0	0.0
Volcanic Glass Rich		36.0	39.7	29.0
Hornblende		9.0	9.0	10.0
Pyroxene		0.0	0.0	0.0
Epidote		0.0	0.0	0.0
Garnet		4.2	4.3	4.3
Muscovite		3.1	3.7	2.1
Fe-Chlorite		0.0	0.0	0.0
Mg-Vermiculite		0.0	0.0	0.0
Apatite		0.82	0.79	0.87
Kaolinite		0.0	0.0	0.0
Calcite		0.0	0.0	0.0

Table 2: Selected summary of input data used for the simulation.

Driver variable			Value					
Average yearly precipitation (mm)			909.07					
Average minimum yearly temperature (C)			Minimum -7.02		Maximum 12.7			
Total yearly radiation (μmol photons$\cdot m^{-2} \cdot s^{-1}$)			4303.5					
Atmospheric Deposition	SO_4	Cl	NO_3	NH_4	Ca	Mg	K	Na
($meq \cdot m^{-2} \cdot a^{-1}$)	78.0	220.0	8.0	7.0	21.0	70.0	4.5	211.0

This confirms the validity of the tree growth module used in ForSAFE-VEG and indicates that the model can be used for predicting forest growth from a productivity perspective. On the other hand, the model predicts badly the size of the soil organic pool and the soil organic C/N ratio, primarily due to the simplifications assumed in the grass growth module. First, the primary biomass production of the ground vegetation and the nutrient ratios in it are uncertain and need to be improved. Second, the creation of litter from the grassy vegetation, in the absence of trees, should be modelled in a way that also accounts for the woody tissues or lignified compounds produced in the litter by this type of vegetation. As data about this system were not available, the assumption was made in the model that the litter produced from the grassy vegetation is made up of celluloses, partly accounting for the reduced long term build up of the soil organic matter. The soil chemistry was calibrated for initial BS, the only calibration carried out in the model. Base cation concentrations as reproduced by the model are in the range of values reported by Gislason et al. (2005), although these reported ranges are wide. The modelled and measured soil solution pH at two different depths is in good agreement (Table 3).

Table 3: Measured and modeled values of some indicator variables.

Variable	Unit	Measured	Modeled
Standing wood biomass	$g \cdot m^{-2}$	10680.0	10120.8
Soil organic carbon	$g \cdot m^{-2}$	26080.0	4830.0
Soil organic C/N	--	18.39	45.0
Soil solution pH 0–5cm	--	5.92	5.96
Soil solution pH 10–30cm	--	6.5	6.71

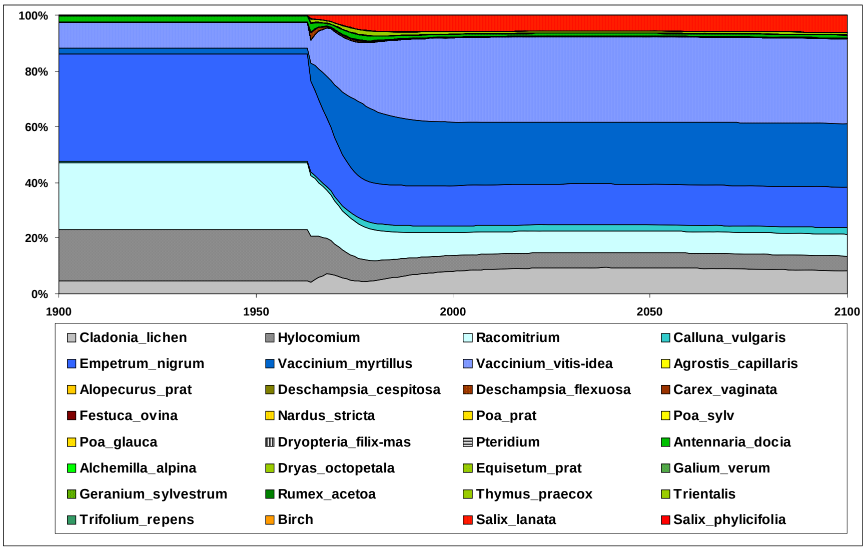

Figure 1: Reconstructed and predicted changes in the ground vegetation. 1964 is the year when grazing was excluded and a forest established.

Changes in the ground vegetation composition are presented in Figure 1. The model predicts a fast change following the exclusion of grazing and the introduction of the forest in 1964. The site's mass index, an indication of how densely covered the site is, not shown in Figure 1, is modeled to have doubled in 1964. This increase is explained by the elimination of grazing pressure. The model predicts a change in the occupancy of mosses, in general being reduced by the introduction of the forest and exclusion of the grazing. There appears also a shift to a greater presence of *Cladonia* spp, suggesting that lichens would establish themselves along with the forest. *Calluna vulgaris*, which was not present before the afforestation, will appear and persist on the site. The composition of the berries would also change with the fraction of *Empetrum nigrum* decreasing in favour of more *Vaccinium myrtillus* and *Vaccinium vitis-idea*. *Deschampcia flexuosa* would appear just after excluding the grazing, but will disappear again after the forest canopy starts to close. *Thymus* spp and *Salix lanata* would become established and would remain in the forest.

The predictions presented above are only an indication of the possibility of changes in the ground vegetation cover as a major change in land use has occurred, namely converting open grazing land to a non-grazed forest. One aspect that may be detrimental but is not included in the model is the dispersal of non-established vegetation, such as *V. vitis-idea*. It may in reality take longer for a plant group to reach a site where it has not previously been present, and this implies that such a plant would have to reach the site exactly when conditions are positive for its establishment. In the model, however, we assume that all included species are readily available and would become established if the conditions are ripe.

While most of the environmental factors affecting the composition of the ground vegetation have been included, the effect of wind has not yet been implemented. Due to the prevalence of winds in Iceland, it is reasonable to believe that including the wind factor may have a great impact on the model reconstruction of the ground vegetation composition. More work is needed on the ground vegetation growth and litter production module, as this seems to be the weakest part of the model. More work is also needed on the dispersion and rate of colonization of different plants.

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2.4 ICEWOODS: Eddy flux measurements over a young *Larix sibirica* stand in eastern Iceland: Measurements and initial results

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Abstract

An eddy covariance system was installed over a 12-year-old stand of *Larix sibirica* in September 2003. The study is a part of a larger research project, ICEWOODS, which focuses on changes in carbon uptake, carbon sequestration in woody biomass and changes in soil efflux of carbon.

The aim of this study it to obtain a better understanding of the carbon balances of afforested heath lands in Iceland. Estimates on the sink/source strength of a chronosequence of areas, afforested by *Larix sibirica* will be made by three different methods; by stock-change approach, by applying ecophysiological modelling, and with direct measurements of annual carbon balance by the eddy covariance technique.

Preliminary results from the eddy covariance measurements show that the uptake of CO_2 is highly related to the global radiation and that during summer time the measurement site is a strong sink.

Keywords: Eddy covariance, ecophysiology, CO_2 flux, NEE

Introduction

Iceland is part of the Nordic Center of Excellence NECC (*Nordic Center for Studies of Ecosystem Carbon Exchange and its interaction with the Climate System*), where the overall aim is to obtain a better understanding of which factors regulate the carbon balance of terrestrial ecosystems. One of the main contributions from Iceland to the NECC is the present study that is used as a PhD study of the first author.

Afforestation of treeless landscapes causes a net carbon (C) sequestration in aboveground biomass (cf. Snorrason et al., 2002). Increasing C-storage in biomass, and possibly soil, is an important part of Iceland's climate strategy. The Icelandic Ministry for the Environment has given out a policy, which includes some plans to enhance carbon sinks through afforestation and revegetation (Ministry for the Environment, 2003). The afforestation should be planned and implemented in such a way that the net carbon sink enhancement will be maximized (Iceland´s National Strategy for Sustainable Development 2002–2020).

The present extent of afforestation in Iceland is about five million seedlings per annum, where of the Siberian larch (*Larix sibirica*) and the native birch (*Betula pubescens*) account for ca. 60% in similar proportions (Sigurdsson, 2001). In the most recent forestry-related legislation the future goal is set to increase woodland and forest cover to at least 5% of the lowland surface area during the next 40 years, which will double the present woodland cover.

Afforestation affects the ecosystem carbon balance not only through changes in aboveground C-stock in standing tree biomass. Some changes also occur in soil organic matter, litter and ground vegetation (cf. Sigurdsson et al., 2005). In young stands and especially when the afforestation has included some site preparation, such as ploughing, the decreases in the soil, litter or ground vegetation C-stocks can be as large or even larger than the accumulation in woody biomass. It is therefore necessary to do more thorough studies of typical afforestation sites (Kyoto-forests), before stating that they generally are carbon sinks.

The general aim of the present research project was to evaluate the effect of afforestation on carbon dynamics in a young Siberian larch plantation. More precise goals of the project were: (a) to quantify by eddy covariance technique the annual net carbon exchange of a typical "Kyoto-forest" of the most common type in Iceland, (b) to evaluate how important different surface types within the young Kyoto-forest (forest patches, open mire patches, open heathland patches) were in the annual C-balance, by using source area calculations and GIS (Geographical Information System), (c) to parameterize an ecophysiological model (BIOMASS) and scale up the annual carbon exchange of different surface types, and (d) to make a comparison of three methods for quantifying carbon sequestration of the afforestation site, (stock-change approach, ecophysiological modeling of annual carbon uptake and emissions and direct measurements of annual carbon balance by the eddy covariance technique).

Material and methods

The study takes place at Vallanes (65°19'N, 14°56'W and 60 m a.s.l.) in eastern Iceland (Figure 1). It is conducted within a larger project in Iceland, ICEWOODS, where data for stock-change approach and ecophysiological modeling is collected for a cronosequence of *Larix sibirica* stands (cf. Sigurdsson et al., 2005). The study site is a 60 ha plantation on former heathland pasture. It was planted in 1992 by Siberian larch (Pinega provenance) mixed with some lodgepole pine (*Pinus contorta*). The stand density is 2338±173 trees ha^{-1} and it has not yet reached canopy closure. At the start of measurements in 2003, the dominant height, DBH and basal area of the trees were 2.4±0.3 m, 0.9±0.2 cm and 0.3±0.1 m^2 ha^1, respectively.

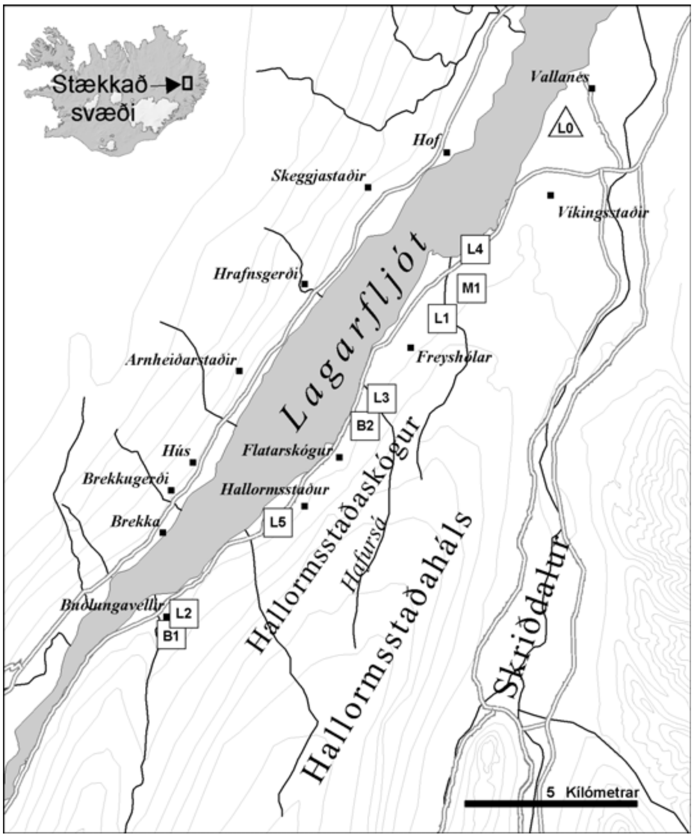

Figure 1. The research area in eastern Iceland. The triangle represents Vallanes.

The soil type of Vallanes is Andosol, a volcanic soil that characterizes Iceland (Arnalds et al., 1995). The ground vegetation consists mainly of dwarf bushes (*Betula nana, Vaccinium uliginosum*), grasses and bryophytes.

The climate in Iceland is characterized by rather cold summers and relatively mild winters. The mean annual temperature (1961–1990) of a near-by synoptic station at Hallormsstaður is 3.4 °C and mean annual precipitation is 738 mm (The Icelandic Meteorological Office, pers. comm.). The mean 24-hour temperature varies between 10.2 °C in July to –1.6 °C in January and mean maximum daytime temperatures are 12.4, 14.1 and 13.4 °C in June, July and August, respectively.

At Vallanes in 2005 the soil was frozen at 30 cm depth until late May and soil started to freeze again in mid October (Figure 2). The prevailing wind directions at Vallanes are north and south and the mean annual wind speed during years 1999–2002 was 4.77 m s^{-1}. In 2005 the mean annual temperature was 4.05 °C (Figure 3) and annual precipitation was around 785 mm in Vallanes. Due to northern latitude (65°N) the global radiation during summer time is high (Figure 4), which can lead to a strong uptake of CO_2 in the ecosystem (trees and ground vegetation).

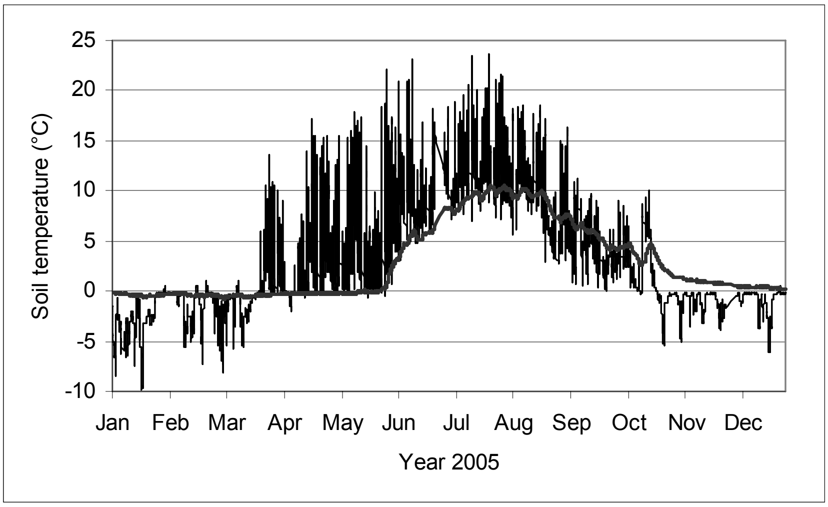

Figure 2. Soil temperature at 1 cm depth (thin line) and 30 cm depth (thick line) at Vallanes in 2005.

Eddy covariance measurements started at Vallanes in September 2003. The eddy system was designed at In Situ Flux, Ockelbo in Sweden. It is an open path system, with LI-7500 CO_2/H_2O gas analyzer and Gill Solent R3 3-d sonic anemometer. It is remotely controlled with its own gasoline generator and two 100 W wind generators. The system measures exchange rates of CO_2, H_2O and sensible heat flux. It also measures some key meteorological factors, such as solar radiation, air temperature and humidity, wind speed and direction and air pressure. The instrumentation is mounted on a mast at the height of 6.5 meters.

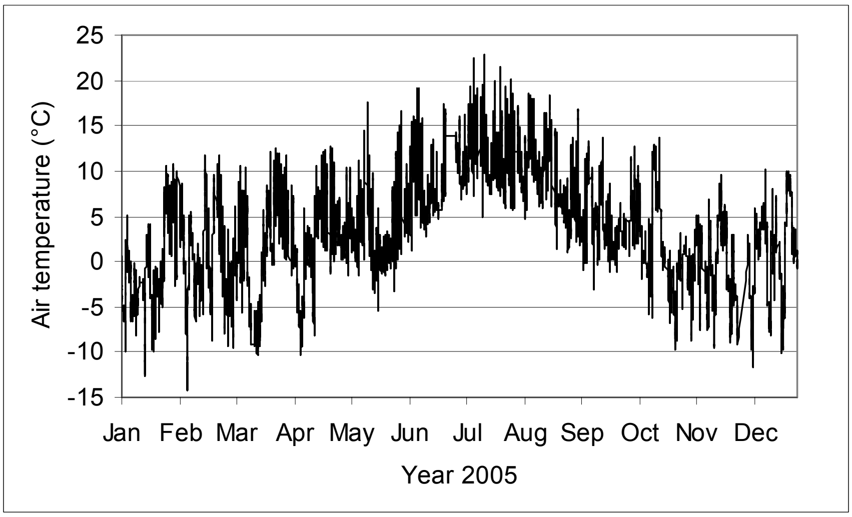

Figure 3. Air temperature at Vallanes during 2005.

Table 1 gives an overview of the instruments used for meteorological measurements. Air temperature and humidity are measured at 2 m, soil temperature is measured at depths of 1 cm, 10 cm and 30 cm, soil moisture is measured at ca. 5–10 cm depth in the soil, soil heat flux is measured at the depth of 2 cm and net radiation and global radiation are measured at 6.5 meters height. Precipitation is measured at 1.5 meters.

Table 1. Overview of the instruments used for measurements at Vallanes.

Environmental factors	Sensors	Environmental factors	Sensors
Micrometerological factors		Carbon	
Net radiation	Kipp & Zonen NR Lite net radiometer	CO_2 fluxes in 6.5 m	LI-7500 CO_2/H_2O gas analyser
Global radiation	LI-200SZ Pyranometer	***H_2O***	
Air Temp and humidity	Rotronic Hydroclip	Precipitation	ARG100 Tipping bucket raingate
Air Temp (in 6.5 m)	Gill Solent R3 3-d sonic anemometer	Evaporation flux	LI-7500 CO_2/H_2O gas analyser
Senisble heat flux	Gill Solent	Soil water potential	Watermark 257 soil water potential sensor
Wind direction	Gill Solent	***Soil***	
Wind speed	Gill Solent	Soil Temperature	TO3R Tojo soil temperature sensors
Air pressure	Vaisala analogue barometer	Soil Heat Fluxes	HFP01SC Hukseflux thermal sensors

Harvest measurements have been used to determine the C-stock in litter and ground vegetation. Soil samples have been taken for determination of soil C-stock. The leaf area index (LAI) of the forest canopy and the forest floor vegetation has been determined during the growing seasons (2004–2005) with a LAI-2000 Plant Canopy Analyzer (LI-COR, Inc). Measurements of LAI will continue through out the study time. To measure annual growth of the trees, both automatic and manual dendrometers have been installed at the study site. These measurements also give us an indication of when the growing season starts and stops. Litter traps are used to capture needles from the trees in order to evaluate carbon stock in litter.

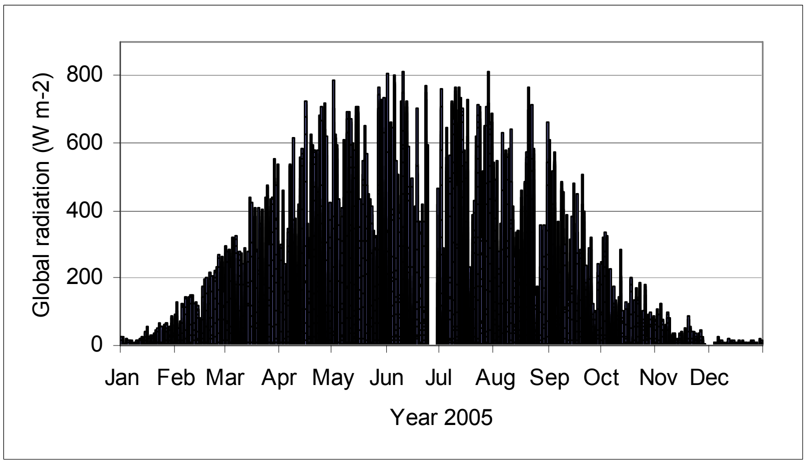

Figure 4. Global radiation at Vallanes during 2005. Gap in June was due to mechanical failure.

Results

Eddy covariance measurements have now been ongoing for two and a half years and will continue through out year 2006. Data analysis has begun and is in process. Several things cause gaps in the eddy covariance data. Most of the gaps occur during wintertime and are mainly due to failure in the energy supply. Gaps can also be related to the anemometer icing up or condensation affecting the gas analyzer. The flux data has now been screened for spikes and the next step is to fill in the gaps to be able to calculate CO_2 balance for longer periods.

To give some idea of the eddy covariance measurements, we here present flux results from Vallanes for August 2005 (Figure 5). Net ecosystem exchange (NEE) of this late summer month was -37 g m^{-2}.

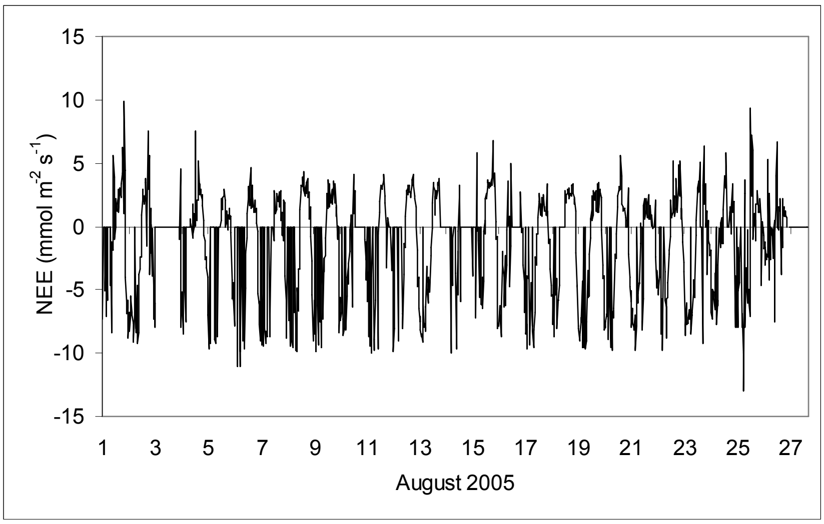

Figure 5. Net ecosystem exchange over 12 year old Larix sibirica plantation in Vallanes, Iceland, during August 2005. Negative NEE-values indicate carbon uptake.

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2.5 ICEWOODS: Changes in ground vegetation following afforestation

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Abstract

The main results of a study on the effects of afforestation with conifers (Siberian larch, Sitka spruce and lodgepole pine) on ground vegetation of open heathlands in Iceland are presented in the paper. In the study a comparison of the ground vegetation of native mountain birch forests and the coniferous plantations was also made. The study was carried out in two separate afforestation areas, in eastern and in western Iceland. The results showed that there was a considerable difference in ground vegetation between the two study areas due to their plantgeographical and climatic differences. However, similar changes in ground vegetation following afforestation occurred in both areas, which were correlated with the age of the forest stands and available light at the forest floor. Species richness was highest in open heathlands and young forest stands but lowest in older stands where light at the forest floor was limited. The results from both study areas indicated that the species richness is higher in the native birch forests than in the coniferous plantations. The conifer trees are much higher than the native birch and less light reaches the ground in very dense coniferous plantations. By managing the forest stands, e.g. by thinning, it is possible to affect their species richness and composition.

Keywords: Plant succession, species richness, Betula pubescens, Larix sibirica*,* Picea sitchensis*,* Pinus contorta*, heathland, Iceland*

Introduction

Tree introductions may cause both large and small scale changes in ecosystem structure that affect species richness and other ecosystem attributes within an area. These changes, e.g. changes in shading, litter characteristics or nutrient content, can easily effect the native ground vegetation (Peterken 2001). It is therefore important to recognize the effects that afforestation may have on the ecosystem. Tree planting has increased considerably in Iceland during recent decades due to governmental support of afforestation in rural areas (Anonymous 1999). The trees planted are a combination of introduced species, e.g. Siberian larch (*Larix sibirica*), lodgepole pine (*Pinus contorta*), Sitka spruce (*Picea sitchensis*), and the native mountain birch (*Betula pubescens*). Parallel to increasing afforestation, there has been an increasing concern about the effects of afforestation on the native biota and ecosystem (Nielsen 2001, Thorhallsdottir 2001).

Information about plant succession that follows afforestation and plant communities of afforested areas is very limited in Iceland. One of the aims of the ICEWOODS project is to elucidate the influence of afforestation on composition and diversity of ground vegetation of open heathlands and to compare the newly established forest stands with the older native mountain birch forests (Elmarsdottir et al. 2007).

Study areas and methods

Two afforestation areas were chosen for the study, one at Fljotsdalsherad in eastern Iceland and the other in Skorradalur and an adjacent area (Litla–Skard) in western Iceland. Eight stands were selected in the eastern area; M: grazed heathland, B1: young mountain birch forest, B2: mature mountain birch forest and L1–L5: five stands of Siberian larch of different age (15–53 years). In the western study area eleven stands were selected; M: grazed heathland, B1–B3: three stands of mature mountain birch forest, G1–G4: four stands of Sitka spruce of different ages (10–44 years) and F1–F3: three stands of lodgepole pine of different ages (15–47 years). Precipitation was higher in the western study area but temperature comparable at the two study areas (Elmarsdottir et al. 2007). Further description of the study areas and experimental design are given in Elmarsdottir et al. 2007.

Within each stand, five plots (2 x 50 m) were randomly placed and used as sample replicates within each type of forest or heathland. Thus a total of 95 plots were set up in the study. Each plot was permanently marked with poles and GPS co-ordinates, allowing future follow–up studies. Within each plot 10 subplots (33 x 100 cm) were placed randomly for all vegetation sampling. All vascular plant species were identified and their cover determined according to Braun–Blanquet cover classes (Goldsmith and Harrison 1976). Also, the cover of five key moss species, *Hylocomium splendens*, *Racomitrium ericoides*, *R. lanuginosum*, *Rhytidiadelphus squarrosus* and *R. triquetrus* was determined. Species cover and frequency data were obtained for each plot or stand. Methods of soil sampling are described in Sigurdsson et al. 2005. Gap fraction (open space in the canopy) of trees was measured every 2 m along each plot (Elmarsdottir et al. 2007). Measurements were made with a pair of LAI–2000 Plant Canopy Analyzers (LI–COR Inc., Lincoln, Nebraska) at the time of maximum leaf area (August–September). The main analysis of the vegetation was carried out with ordination and classification by using the PC–ORD program (McCune and Mefford 1999). The vegetation ordination was based on the frequency of 124 vascular species and five key moss species identified within the different stands. In the ordination analysis a correlation of environmental and vegetation variables with the ordination axes was found, as given by the program. In DCA ordination downweighting of rare species was chosen in the analysis. The same data set was used in a TWINSPAN classification.

Results and discussion

Comparison of study areas and forest stands of different ages

The results of TWINSPAN classification based on 95 plots from the two study areas showed that the greatest contrast in the vegetation was between heathland/young forest stands and the old forest stands. This was revealed in the first division of the TWINSPAN tree (Figure 1). The second division, on the other hand, gave a clear separation of the two study areas. Heathland and young forest stands from the eastern area were grouped together and separated from the western area. Similarly in the old forest groups, the older forest stands from the western area were separated from stands from the eastern area. This shows that the ground vegetation of the heathlands and younger forests differed from that of the older forests as well as that there were regional differences in the flora of the two study areas. The third division of the classification also showed that birch stands in the eastern area separated from the older larch stands. Similarly, in the western study area the birch stands separated from the older conifer stands; however two Sitka spruce plots were in the same class as the birch.

The ordination revealed a distinct difference in the vegetation between the two study areas on one hand (axis 2) and the heathland sites and plots from the different age forest stands on the other (axis 1) (Figure 2 and 5). The differences between the study areas can be explained by floristic differences between western and eastern Iceland, and the fact that the western study area receives more precipitation and has richer soils. Thus *Campanula rotundifolia*, *Vicia cracca* and *Trientalis europaea* are examples of species only encountered in the eastern study area while *Vaccinium myrtillus*, *Gymnocarpium dryopteris* and *Fragaria vesca* were only recorded in the western area. In the western area average soil pH for all plots was 5.8 (±0.4 s.d.), C % 11.4 (±4.5 s.d.) and N % 0.7 (±0.2 s.d.) compared to pH 6.5 (±0.4 s.d.), C % 4.4 (±2.2 s.d.) and N % 0.3 (±0.1 s.d.) in the eastern area.

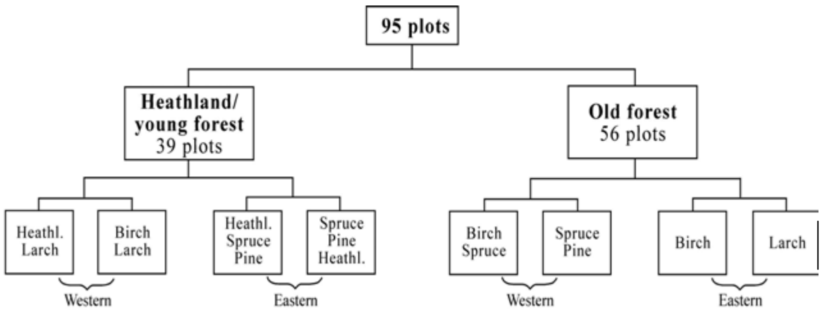

Figure 1. Results of TWINSPAN classification of vegetation in plots from eastern and western study areas.

Despite differences between the study areas, similar changes occurred in ground vegetation following afforestation. Cover of vascular species, mosses and lichens decreased in both areas as the forest grew older and became denser (Figure 2). In both areas species richness was highest in open heathland and young forests but was found to be lowest in old and unthinned forests where the canopy gap fraction was low and therefore limited light at the forest floor (Figure 2 and 3). Plant species that were dominant in the heathland and the young forest stands are common heathland species and adapted to the open habitats, e.g. the shrubs *Empetrum nigrum*, *Calluna vulgaris* and *Dryas octopetala* and the sedge *Kobresia myosuroides*. The open heathland and the young forest stands were relatively rich in mosses and lichens compared to the older forest stands (Figure 3).

In the denser forest stands species adapted to open habitats retreated while shade tolerant species invaded the forest or became more common in the vegetation (Figure 4). Common species found in the ground vegetation of forest stands were the horsetail *Equisetum pratense*, the sedge *Carex vaginata*, the grass *Deschampsia flexuosa*, and the forbs *Rubus saxatilis* and *Geranium sylvaticum*. Mosses were more abundant in those habitats, e.g. *Hylocomium splendes* and *Rhytidiadelphus triquetrus*.

Our findings are coherent with other studies that have shown that light availability is the main factor that influences vegetation composition and species diversity (Wallace 1995, Stone and Wolfe 1996, Engelmark et al. 2001). Similarly understory biomass in the eastern study area was strongly related to canopy gap fraction across forest stands (Sigurdsson et al. 2005). Thus relatively species rich communities of open heathland will not persist after afforestation. They will be replaced by species poorer communities of horsetails, monocots and forbs, which at the thicket stage may have extremely low plant cover and species richness. Similar to other studies, this shift in vegetation composition reflects changes in the relative proportions of many of the species present, rather than an introduction of new species (Hill and Jones 1978).

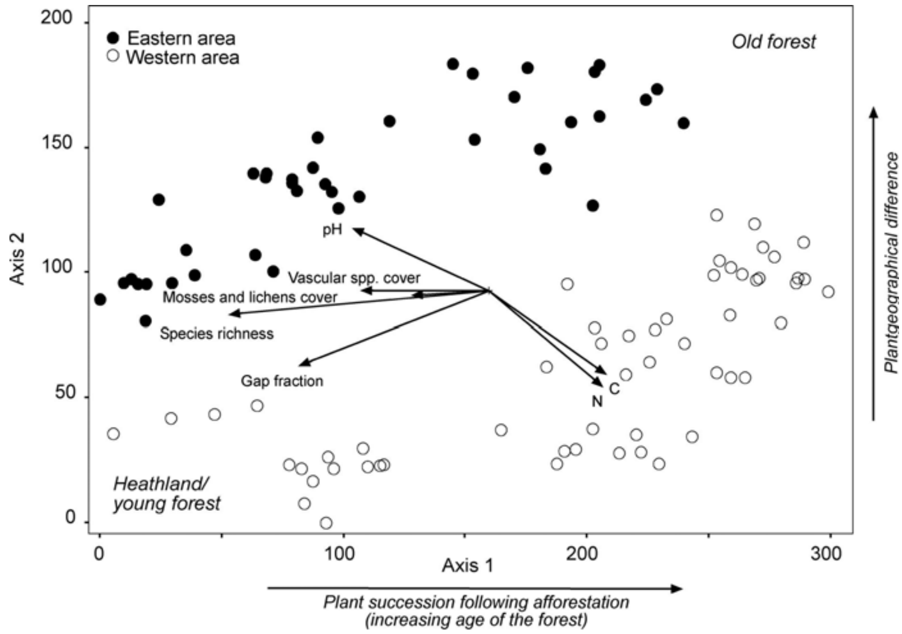

Figure 2. Results of DCA–analysis of vegetation variation of plots from the eastern and western study areas and correlation with environmental and vegetation variables. Arrow direction indicates direction of main change for the variable and length the strength of the correlation.

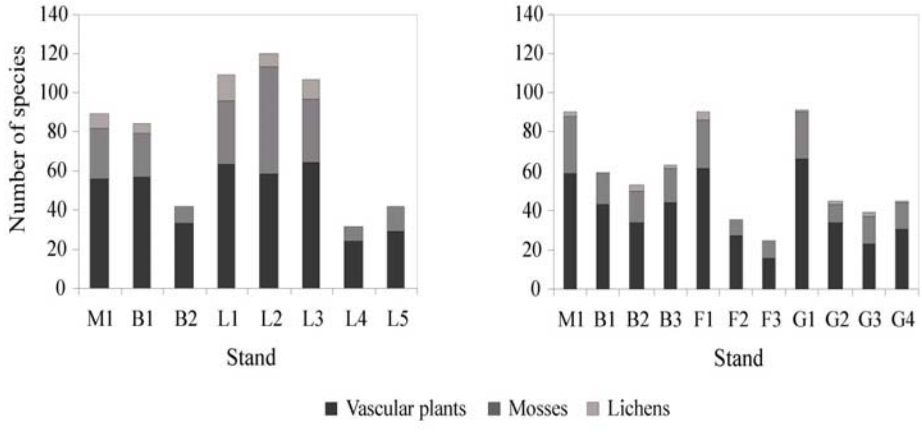

Figure 3. Average species richness (vascular plants, mosses and lichens) within a plot in the eastern (left) and western study area (right). M: heathland, B: birch, L: larch, G: spruce, P: pine stands of different ages.

Comparison of native birch forests and coniferous plantations

The results showed that species richness was considerably higher in the native birch forests in comparison to the old coniferous plantations. The total number of species found in the birch forests was 42–84 compared to 25–45 species in the older coniferous plantations (Figure 3). The ordination results showed that the ground vegetation of the birch forests was not as distant from the open heathland and young forest stands as that of the densest coniferous stands (e.g. G3, G4 and F3) which were characterized by very low species diversity and plant cover (Figure 3 and 5). Dicots were more common in the birch forests compared to the old coniferous forests where horsetails, sedges and grasses were more abundant. Common vascular species in the birch forest were the shrubs *Vaccinum uliginosum*, *Salix lanata*, *Empetrum nigrum*, the forb *Rubus saxatilis* and the grasses *Deschampsia flexuosa* and *Agrostis capillaris*. Moss cover was in general higher in the birch forest than in the coniferous plantations. During the thicket stages the coniferous stands are relatively poor habitats for plants in comparison to the native birch forests. This is mainly due to the very limited light that reaches the forest floor in the dense coniferous stands, a condition that is not attained in the birch forests (Elmarsdottir et al. 2007).

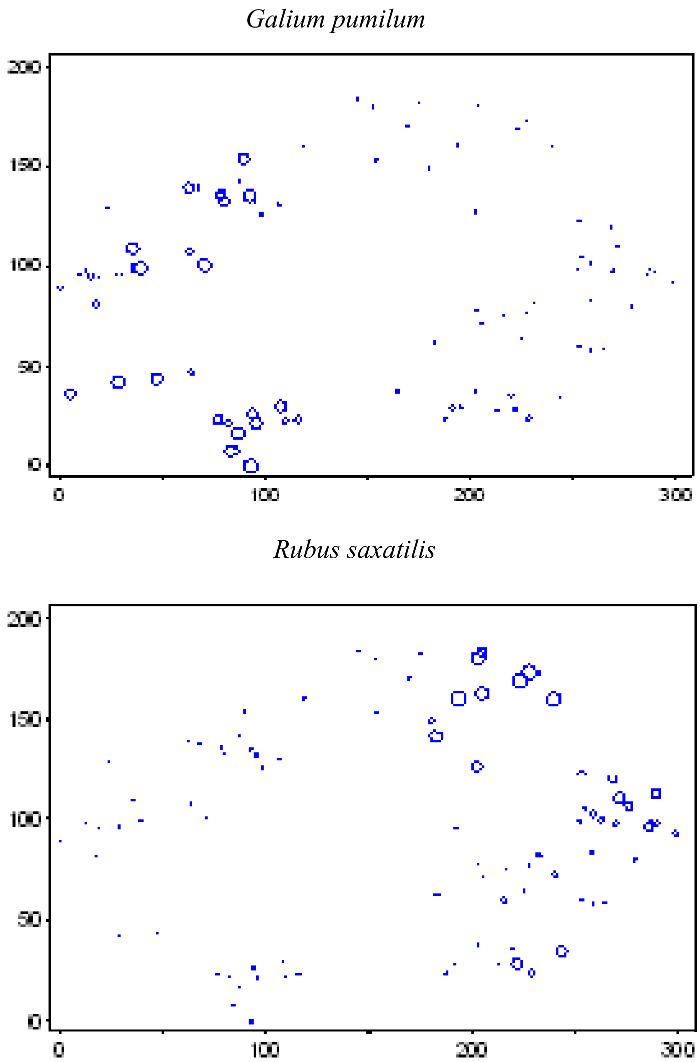

Figure 4. Example of species that retreat (Galium pumilum) or increase in abundance (Rubus saxatilis) following afforestation.

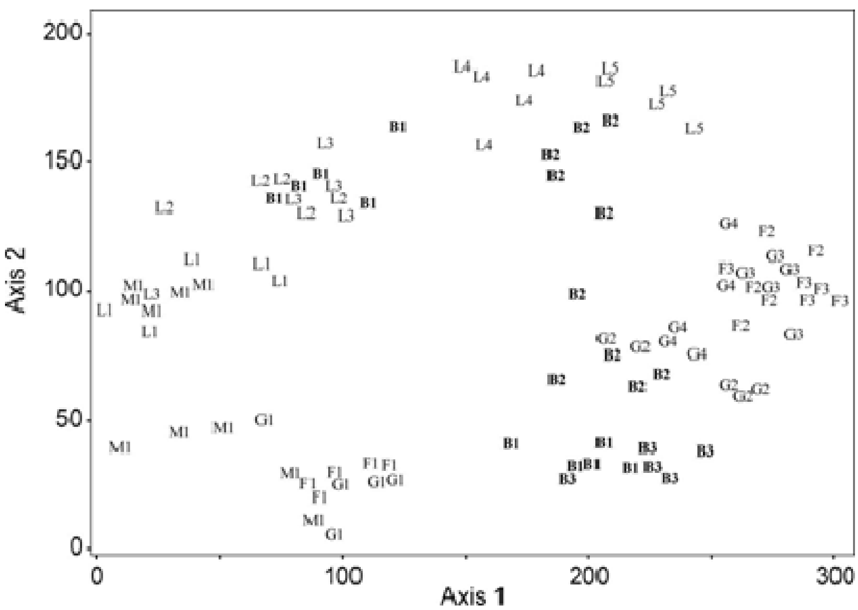

Figure 5. Results of DCA analysis of variation in vegetation in plots from the two study areas and the position of the native birch stands (bold) compared with other stands. M: heathland, B: birch, L: larch, G: spruce, P: pine stands of different ages.

Conclusions

During recent decades increased emphasis has been placed on conserving biological diversity, threatened habitats and ecosystems in Iceland (Ministry for the Environment and the Icelandic Institute of Natural History 2001). As has been pointed out, afforestation is increasing in Iceland and one of the main emphases is on timber production (Aradottir and Eysteinsson 2005). These two goals may contradict each other. The results of our study imply that by managing the forest stands, e.g. thinning, it is possible to affect their species richness and species composition. Similarly, Wallace and Good (1995) suggested increased multi–use forestry with wildlife conservation as an objective with two main alternatives. One was to manage the forest with heavy thinning and the other alternative was to grow broadleaf species, in a mixture with the conifers, which naturally cast less shade.

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2.6 ICEWOODS: Age–related dynamics in biodiversity and carbon cycling of Icelandic woodlands. Experimental design and site descriptions

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Abstract

It is foreseen that afforestation will increase in the near future in Iceland. There has been an ongoing debate on what effects afforestation will have on biodiversity and the ecosystem overall. To answer some of the questions that have been raised the ICEWOODS project was started in 2002 to investigate how afforestation would affect biodiversity and ecosystem productivity. The project is run co-operatively by the Icelandic Institute of Natural History, Icelandic Forest Research, Agricultural University of Iceland and Regional Afforestation Programmes.

In the project two study areas were selected, one in eastern Iceland and the other in the western part. In each area, open heathland, coniferous plantations of different ages as well as native mountain birch forests were studied. In the eastern area there were, besides the heathland, five stands of Siberian larch and two stands of mountain birch. In the western area there were an open heathland site, four stands of Sitka spruce, three stands of lodgepole pine and three stands of mountain birch. In this paper the background and the design of the project will be described. In both study areas the dominant height of the oldest coniferous trees was higher than that of the oldest birch trees. Stand density was, on the other hand, similar among stands, except where thinning had been applied. Less light was encountered at the forest floor in old coniferous stands that had not been thinned compared to other forest stands.

Keywords: Afforestation, *Betula pubescens, Larix sibirica, Picea sitchensis, Pinus contorta*, heathland, Iceland

Introduction

Iceland has few native tree species and mountain birch (*Betula pubescens*) is the only species that has formed woodlands during the Holocene (Kristinsson 1986, Hallsdottir 1995). Since human settlement in the 9th century forest cover has declined from about 25% to 1% of the land cover, mainly due to anthropogenic disturbances (Thorarinsson 1961, Sigurdsson 1977, Arnalds 1987). Today the birch cover is mostly confined to small and scattered woodland units.

Organized forestry began in Iceland early in the 20th century and focused on protecting the birch forest remnants as well as on planting exotic coniferous species (Sigurdsson 1977, Aradottir and Eysteinsson 2005). For the past few years the native mountain birch and the introduced Siberian larch (*Larix sibirica*), Sitka spruce (*Picea sitchensis*) and lodgepole pine (*Pinus contorta*) have accounted for about 80% of the annual afforestation in Iceland (Petursson 2002). In 1999, an Act on Regional Afforestation Programs took effect (Anonymous 1999). The aim of the programs is to increase forest cover to at least 5% of the lowland area during the subsequent 40 years. These programs are subsidized by government funding and are practiced by farmers and other private landowners. The majority of farmers and landowners emphasize timber production, but others focus on other values, e.g. shelterbelts, improved grazing for livestock and outdoor recreation (Aradottir and Eysteinsson 2005). Parallel to the increasing afforestation, there have been ongoing debates on what effects afforestation will have on biodiversity and the ecosystem overall (Thorhallsdottir 2001, Nielsen 2001).

To answer some of the questions that have been raised the ICEWOODS project was started in 2002 to investigate the effects of afforestation on biodiversity and forest production. The project is run cooperatively by the Icelandic Institute of Natural History, Icelandic Forest Research, Agricultural University of Iceland and Regional Afforestation Programmes. The project has been funded by several sources, but mainly by the Icelandic Research Council, Icelandic Agricultural Fund, Nordic Council of Ministers and the active partners themselves. The goal of ICEWOODS is to study the influence of afforestation on the ecosystem. Three main components are studied, where open heathland is converted to forest:

- Biodiversity
  - Changes in communities of arthropods, flora, fungi and birds.
- Ecosystem productivity
  - Changes in productivity and carbon fluxes.
- Soil characteristics
  - Changes in carbon, nitrogen and acidity of the soil.

Study areas

Two study areas were selected for the project, one in the eastern part of Iceland and the other in the western part (Figure 1 and 2). The study area in the east is located at Fljotsdalsherad (65°06'N, 14°46'W) at an elevation of 60–90 m a.s.l. The western area is located in Skorradalur (64°30'N, 21°27'W) at an elevation of 60–200 m and the adjacent Litla–Skard in Nordurardalur (64°44'N, 21°37'W), which is 120–140 m a.s.l. and about 25 km from Skorradalur. Both at Fljotsdalsherad and Skorradalur the study areas are located on valley slopes, which are steeper in the Skorradalur study area. At Litla–Skard the land is flatter. The bedrock in both study areas is basalt from upper Tertiary (Johannesson and Saemundsson 1998). Mean temperature in January and July is fairly similar in the eastern and the western area (Table 1). More variability is found in precipitation between the areas, which is higher in Skorradalur but much lower in the eastern area and Litla–Skard.

At both study areas there are comparable coniferous forests of different ages, which allow for an age–sequence study (chronosequence) of the effects of afforestation on ecosystems. There are open heathlands used for sheep grazing, planted conifer forests of introduced species and remains of native mountain birch woodlands. The older birch forests found in both study areas are remains of the ancient birch woodlands of Iceland. In the western study area, all forest types and age classes were located in Skorradalur except one birch forest which was located at Litla–Skard.

Table 1. Mean temperature in January and July and annual precipitation in the eastern and western study areas.

	Eastern area	Western area	
		Skorradalur	Litla–Skard
January (°C)	–1.6 [1]	–2.4 [2]	–2.9 [2]
July (°C)	10.2 [1]	9.7 [2]	10.0 [2]
Precipitation (mm)	738 [1]	1425 [3]	865 [4]

[1] Mean 24–h temperature and annual precipitation 1961–1990 at the synoptic station at Hallorms-stadur. [2] Mean 24–h temperature 1961–1990 (Bjornsson 2003). [3] Annual precipitation 1961–1990 at the synoptic station Andakilsarvirkjun. [4] Annual precipitation 2001–2004 at the synoptic station Litla–Skard (Sigurdsson 2005).

Experimental design

In both study areas several forest stands of different age–classes were selected within a relatively small and homogeneous area and an open heathland site was selected for comparison (Table 2). The planted coniferous stands in both study areas and the younger birch stand in the eastern area were grazed heathland prior to afforestation. Within each stand all trees where planted within a one to three year period. The size of each stand is 1.2–9.5 ha. All data were collected within the stands except in the studies of birds. See other papers in the proceedings for further details on methods of each sub-project within ICEWOODS.

Figure 1. The eastern study area. M= open heathland, L1–L5= planted Siberian larch age–sequence and B1–B2= native birch age–sequence.

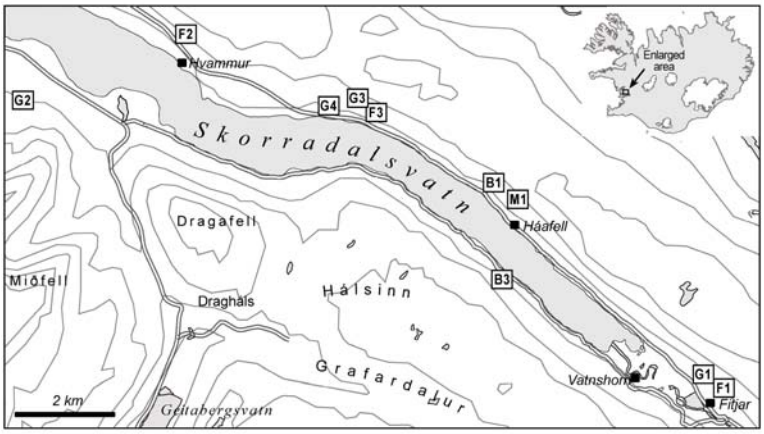

Figure 2. The western study area. M= open heathland, G1–G4= planted Sitka spruce age–sequence, F1–F3= planted lodgepole pine age–sequence and B1 and B3= native birch. One birch stand (B2) was located ca. 25 km northwest of this area, at Litla–Skard.

Eight stands were selected in the eastern study area (Figure 1, Table 2), one site of grazed heathland, one stand of mature mountain birch forest which had not been grazed for 100 years, a young birch stand that had regenerated naturally following fencing and protection from grazing for about two decades, and five stands of planted introduced Siberian larch. The area of the oldest larch (L5) was protected from grazing in 1905 as the older birch forest (B2). At that time the L5 forest stand was a treeless heathland (Palsson 1931) but had partly been colonized by native birch when it was planted by Siberian larch in 1952 (S. Blondal, pers. comm.). The age of the Siberian larch stands ranged from 15–53 years. The oldest larch stand (L5) had first been mildly thinned in 1971 and the following years and then had its second thinning in 1992, which was of normal density. L4 had had one mild thinning in 1990, but the thinning density was very low, so its effects on growth and light conditions were minor.

Table 2. Type of each stand, size (hectare) and the year of planting or protection from grazing.

	Type of stand	Area (ha)	Time of planting/protection from grazing*
Eastern area			
M	Heathland	7.4	
B1	Birch	5.1	1979*
B2	Birch	6.1	1905*
L1	Siberian larch	4.6	1990
L2	Siberian larch	7.2	1984
L3	Siberian larch	9.5	1983
L4	Siberian larch	3.2	1966
L5	Siberian larch	7.3	1952
Western area			
M	Heathland	>3	
B1	Birch	>3	
B2	Birch	>3	
B3	Birch	>3	2004*
G1	Sitka spruce		1995
G2	Sitka spruce	1.2	1970
G3	Sitka spruce	3.2	1960–61
G4	Sitka spruce	4.1	1961
F1	Lodgepole pine	>3	1990
F2	Lodgepole pine	>2	1965–68
F3	Lodgepole pine	1.8	1958–59

Eleven stands were selected in the western study area, ten located in Skorradalur and one (B2) located in Litla–Skard. The stands selected were one site of grazed heathland, three stands of mature mountain birch forests, four stands of introduced Sitka spruce and three stands of introduced lodgepole pine. The age of the Sitka spruce and lodgepole pine stands ranged from 10–44 and 15–47 years, respectively. In the western study area only the oldest Sitka spruce stand (G4) had been normally thinned in 1996. It should be noted that the birch stands in the western area were all mature stands and did not represent a chronosequence.

Data sampling

To determine dominant tree height, stand density and basal area, three to five randomly placed 50–100 m^2 circular plots were used as sample replicates within each forest stand. Diameter at breast height (DBH, 1.3 m) was measured by callipers for all trees within plots and diameter at 50 cm was also measured for all mountain birch trees and coniferous trees < 3 m in height. Tree height was measured by telescopic pole for 10–12 chosen trees in five different diameter classes in each plot. Here we only show the dominant height, i.e. the average height of the 5 trees with the highest DBH in the plots.

Gap fraction (amount of open space in the canopy) of tree canopies was measured with a pair of LAI–2000 Plant Canopy Analyzers (LI–COR Inc., Lincoln, Nebraska) at the time of maximum leaf area (August–September). One instrument was placed in a clearing and the other was used to take readings of sky brightness every 2 m along 50 m randomly placed transects in all forest stands (n = 5). Measurements were made during an overcast day, sensor heads always faced north and a 180° lens cap was used.

Forest characteristics

Dominant tree height, stand density and gap fraction were used to describe the structure of each stand (Figures 3 and 4). In both study areas the dominant height of the oldest coniferous stands was much higher than that of the old birch stands. It must also be noted that the coniferous stands in this study were fairly young and will increase their height somewhat. The stand density of trees in the eastern area was similar, both in stands of native birch and introduced larch, except in the oldest larch stand (L5), which had been thinned twice. However, the two birch stands had more secondary stems than the larch stands (Sigurdsson et al. 2005). In the western area the stand density in B1 and B2 was higher than was measured in the other forest stands, which was partly explained by the lower stature of the trees. There, more individuals could get growing space per area because of the low stature. The stand density in the coniferous plantations was similar, except in G4, which had been thinned once (Figure 3).

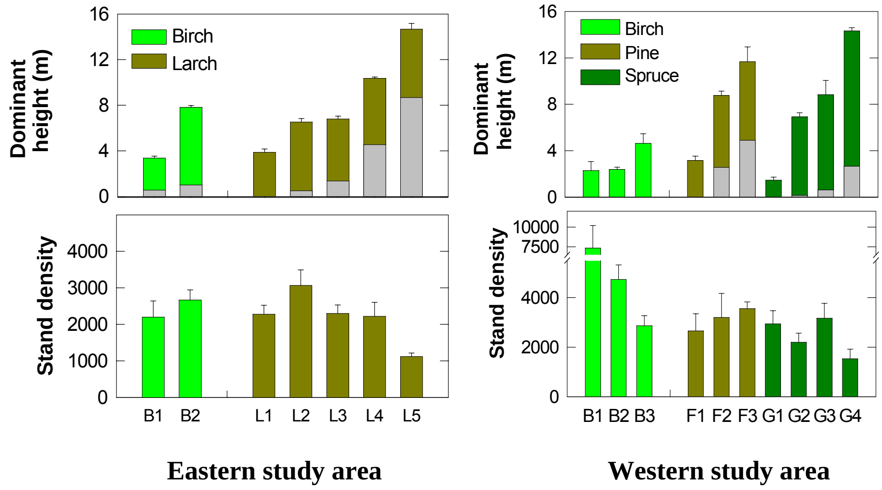

Figure 3. Dominant height of trees and stand density of forest stands in the two study areas. Each bar indicates an average (+SE) of three to five 100 m^2 plots in each forest stand. Coloured bars for dominant height indicate average canopy depth in a stand. B = mountain birch, L = Siberian larch, F = lodgepole pine, G = Sitka spruce.

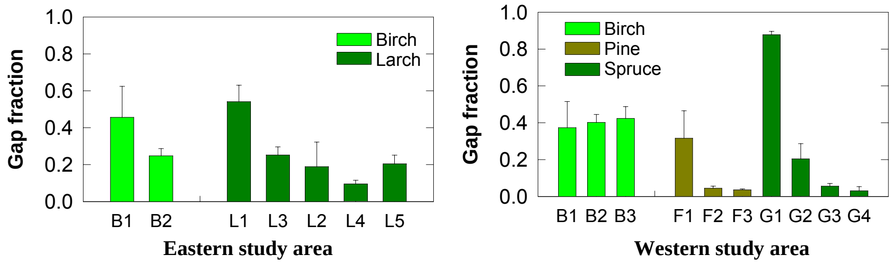

Figure 4. Gap fraction (amount of open space) of forest stands in the two study areas in eastern and western Iceland. B = mountain birch, L = Siberian larch, F = lodgepole pine, G = Sitka spruce. For further information see Table 1. Each bar indicates an average (+S.d.) of five transects in each forest stand.

Gap fraction varied both between tree species and age classes (Figure 4). The gap fraction of the youngest forest stands was fairly high as the trees were still small and the canopy open. Mature mountain birch always had 30–40% openings in its canopy, both in eastern and western Iceland. The gap fraction in larch was lowest in the practically unthinned L4, ~10%, but had increased to ~21% in the twice thinned L5. The two oldest unthinned pine stands (F2 and F3) and the unthinned spruce stand (G3) all had a 4–5% gap fraction. The lowest measured gap fraction was in G4, which only had ~3% openings in the canopy, even if it had been thinned once nine years earlier.

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2.7 ICEWOODS: Fungi in larch and birch woodlands of different age in Eastern Iceland

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Abstract

Based on fungi collected in the middle of August 2003 and the middle of September 2004 in the ICEWOODS experimental stands in Fljótsdalshérad, Eastern Iceland, the species composition of fungi for each stand was established. There were eight stands, one stand of heath without trees; five Siberian larch stands with the youngest (L1) and the oldest (L5) 13 and 53 years of age respectively; and two birch stands, young (B1) and (B2) 25 and 96 years of age respectively.

The old birch stand (B2) had the highest number of species but the young birch (B1) and the oldest larch (L5) had only slightly fewer. Species counts in the larch stands L2 and L4 fell in the middle, with the lowest number in the youngest (L1) larch stand, the heath (M), and the third youngest (L3) larch stands. Preliminary results from the ICEWOODS experimental site in Western Iceland are also presented.

A total of 117 species have been identified, 99 species from the East site and 42 from the West site. Available substrates or host species for ectomycorrhizal fungi and parasitic fungi accounted for much of the difference in species composition of fungi present in each stand. Ten species of fungi were recorded for the first time in Iceland in this study, seven in the East site and three in the West site.

Keyword. Fungi, mycorrhizae, decomposers, biodiversity, Iceland

Introduction

Fungi play many roles in the forest ecosystem. Some are symbiotic and form mycorrhizae with their host trees, some are parasitic and grow on plants, animals or other fungi, some are epiphytic and use the hosts only to sit on, and many are saprophytic breaking down dead material and thus being essential to nutrient cycling. Fungi serve as food for mites and collembolans which feed on their mycelium and for insects which lay their eggs in fruiting bodies which serve as a food source and shelter for the larvae. Snails and various mammals feed occasionally on mushrooms and the larvae from within the fruiting bodies serve as food for birds.

Trees obtain water and nutrients from the soil through their mycorrhizal fungi, especially nitrogen and phosphorus, but the fungi get carbohydrates from their host trees, usually 10–25% of what the trees produce of photosynthate (Kendrick 1992, Read & Perez-Moreno 2003). These carbohydrates are transferred via the fungal mycelium from the roots and into the mycelium in the soil. Although much of the carbon is released from the soil as CO_2 through respiration in the fungal cells, some of it remains in the soil when old parts of the mycelium die. Each tree usually has several mycorrhizal fungi on its root system and the mycelium of one fungus can be connected to more than one tree and sometimes to more than one tree species.

Much of the knowledge of the mycota of Icelandic woodlands is based on fungi observed or collected by Helgi Hallgrímsson and others who have deposited specimens or records in the herbarium of the Icelandic Institute of Natural History, Akureyri Division (AMNH). From the herbarium database, lists of species collected at a specific site or in a specific habitat can be generated. From native birch woods numerous fungi have been recorded and many species have birch woods or birch listed as their habitat or substrate in the checklist of Icelandic fungi (Hallgrímsson & Eyjólfsdóttir 2004, Hallgrímsson & Eyjólfsdóttir in preparation) but no recent accounts of the species composition of specific woodlands have been published. In the checklists the literature treating each species is listed, its habitats or substrates, known distribution within Iceland and its frequency. Hallgrímsson (1998) wrote about the lignicolous basidiomycetes, many from birch woodlands, and he also reported on mycorrhizal fungi of Siberian larch (Hallgrímsson 1987). Eyjólfsdóttir (1999) reviewed the information on microfungi on dead branches of Siberian larch in Iceland and Eyjólfsdóttir *et al.* (1999) and Halldórsson *et al.* (2001) reported on the parasitic microfungi of trees and the damage caused by them and their known distribution.

Material and methods

Fungi were collected in the ICEWOODS experimental stands in Fljótsdalshérad, East Iceland (East site) in five stands of Siberian larch of different ages L1 (13 years old), L2 (21 years old), L3 (21 years old), L4 (40 years old), and L5 (53 years old), and in a young native birch stand, B1 (25 years of age), and an old stand, B2 (96 years of age) with heath without trees (M) for comparison. The stands are described in more detail in a separate paper (Elmarsdóttir *et al*. 2007). Collections were made on the 11–14th Aug. 2003 and, in order to obtain those species which fruit late in the season, again on the 14–15th Sept. 2004. The first collection of fungi in the ICEWOODS experimental stands in Western Iceland (West site) was done on 16–20th Aug. 2004 with the second planned for September 2005. The West site consists of one treeless heath (M) and three different birch stands (B1, B2, B3). There are four Sitka spruce stands of different ages (G1: 10 years old, G2: 35 years old, G3: 45 years old, G4: 44 years old, thinned) and three lodgepole pine stands of different ages (F1: 15 years old, F2: 38 years old, F3: 47 years old) which are described in more detail in a separate paper (Elmarsdóttir *et al.* 2007).

From each stand a sample of fruiting bodies of each species found was collected at least once. The material was photographed and identified as to species when possible. Descriptions of the fresh material were made for those specimens that represented rare or interesting species or were difficult to assign to a species. The specimens were subsequently dried at 35–40 °C in a vegetable dryer, labelled and are stored in the mycological herbarium of the Icelandic Institute of Natural History, Akureyri Division (AMNH). The dried specimens of several of the more difficult genera were later studied microscopically in order to identify or confirm identification based on fresh fruiting bodies. However, several specimens could only be assigned to a genus.

For each species the most appropriate lifestyle or functional group was selected. The saprophytic fungi were further divided into those which fruit on the ground (sapr), on the leaves and small branches on the forest floor (litter) and those which fruit on wood or bark of larger branches or stems of dead trees (wood). The other lifestyles were ectomycorrhizal, (EM) with the single endomycorrhizal fungus recovered in this study included, epiphytic (epiph) and parasitic to plants, insects or fungi (paras).

The species of microfungi not listed in the checklist of Icelandic fungi (Hallgrímsson & Eyjólfsdóttir 2004) and the species of basidiomycetes not listed in the manuscript of the checklist of Icelandic fungi – basidiomycetes (Hallgrímsson & Eyjólfsdóttir in preparation) were considered as new records for Iceland.

Results and discussion

At this date a total of 194 specimens have been processed from the material collected in August 2003 at the East site and 129 specimens from the material collected in September 2004. These specimens have been identified to 99 different species and an additional ten species have been identified to a genus. Of these, 69 were found the first year, and the second year 30 species were added. Seven species were recorded for the first time in Iceland, thereof one as an unidentified *Mycena sp*. These were the anamorphic mycoparasite *Isaria brachiata* (Batsch) Schumach. growing on decaying fruiting bodies of *Pluteus cervinus* in L4. Another anamorphic mycoparasite *Gliocladium roseum* Bainier. was found growing on aging *Stereum rugosum* fruiting bodies in B2. The only endomycorrhizal fungus recovered in this study was *Glomus macrocarpum* Tul. & C. Tul. in L4. A pale brown discomycete *Trichophaea hybrida* (Sowerby) T.

Schumach. grew on larch litter near decaying stems of larch in L4. The myxomycete *Physarum nutans* Pers. was discovered forming its tiny sporangia on the bark of a rotten larch branch in L5. The agaric *Mycena vulgaris* (Pers.: Fr.) P. Kumm. grew on larch litter in L4. And the last of the seven was a pure white and tiny *Mycena sp*. growing on decaying moss buried in larch litter in L3.

At the West site the results were based on material collected in the middle of August 2004 after a warm and dry period when relatively few fungi were fruiting. From the material collected 118 specimens have been processed and identified to 42 species. Ten additional species have been identified to a genus. Three species were recorded for the first time in Iceland: the agarics *Fayodia bisphaerigera* (J.E. Lange) Singer var. *bisphaerigera* growing near buried branches of spruce in G4, *Hemimycena lactea* (Pers.: Fr.) Singer var. *lactea* on spruce litter in G4, and *Cortinarius vibratilis* (Fr.) Fr. mycorrhizal fungus in G2, G3 and G4.

The results of research on biodiversity of fungi at the West site are only preliminary. The fewest species were recorded in heath (2 species) and in the youngest spruce stand (3 species) while 13 and 12 species were recorded in the tallest birch stand (B3) and the oldest spruce stand (G4) respectively (Figure 2). In the heath (M) and the youngest spruce (G1) stands no macrofungi were recorded and the only fungi collected were parasitic on vascular plants. In the other stands the majority of species were ectomycorrhizal (EM) while the fungi growing on litter were only present in 5 of the stands and only one or two species in each stand, usually found where some moisture was retained. Thus at least some of the ectomycorrhizal fungi appear to be able to fruit in much dryer conditions than the fungi colonizing the litter on the forest floor.

At the East site the fewest species were found in the youngest larch stand (L1) 14 species. In the heath stand (M) 18 species were found and in the 21 year old larch stand (L3) 19 species. In two of the larch stands L2 and L4 there were 26 species or an intermediate number of species, whereas the young birch (B1) with 31 species, the oldest larch (L5) stand with 33 species and the old birch stand (B2) with 40 species were the three stands with the highest number of species (Figure 1).

When the lifestyles of the species were plotted for each stand the species of ectomycorrhizal fungi in the two birch stands were twice as many as in the larch or heath stands (Figure1). Fungi fruiting on wood were only present in three stands: L4, L5 the only two larch stands which had been thinned, and B2 where many stems were dead either still standing or decaying on the forest floor. Since many fungi grow on decaying wood and the bark of dead trees it greatly increases the fungal diversity if decaying trees or logs are present in the stands. If the decaying wood is both deciduous and coniferous, as in L5 where there were remnants of birch among the wood of larch which had been felled when the stand was thinned, the potential for diversity of lignicolous fungi is high. The saprophytic fungi which form their fruiting bodies on litter were absent from the heath (M) and there were only relatively few in the birch stands, but on average they comprised 31% of the species in each larch stand, where some of them, i.e. *Spathularia flavida*, *Gymnopus dryophilus*, and *Clitocybe cerussata*, were very common, producing numerous fruiting bodies on the mats of decaying larch needles, especially in 2003. At least seven species, i.e. *Agaricus campestris*, *Calvatia cretacea*, *Conocybe sp*., *Hygrocybe conica*, *Lactarius torminosulus*, *Hebeloma crustuliniforme*, and *Melanoleuca strictipes*, were restricted to the heath (M) whereas two, *Collybia obscura* and *Entoloma serrulatum*, were common in the heath and were present only in areas without litter in the youngest larch stand (L1). Saprophytic fungi fruiting on the ground were the most common in the heath (M) or 61% of the species recorded with that lifestyle.

To date 117 species of fungi, of which two species had two varieties, have been identified in the two ICEWOODS sites. After collecting twice at the East site at times when fungi were fruiting well the majority of the more common species of macrofungi would have been recorded but the less common species, especially those which produce small fruit bodies, are likely to remain unrecorded. The same applies to those species which require special conditions before fruiting or only fruit rarely. Documenting the mycota of any area requires considerable time and effort in order to locate the rare and inconspicuous species.

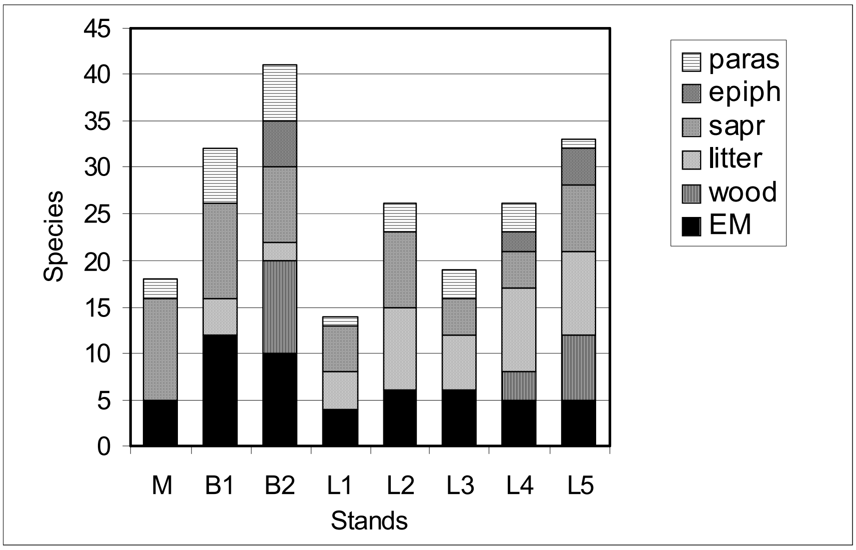

Figure 1. Fungi in ICEWOODS stands at Fljótsdalshérad Eastern Iceland and their life styles.

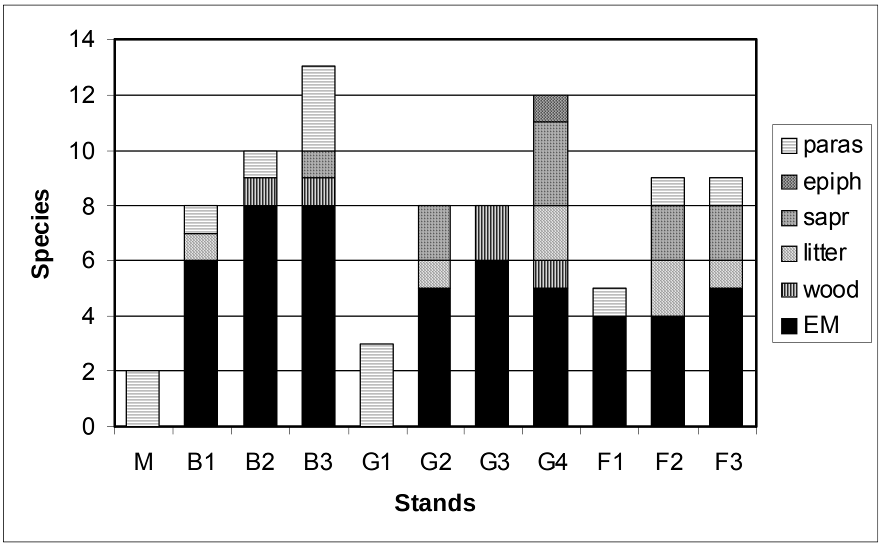

Figure 2. Fungi in ICEWOODS stands in Western Iceland and their life styles.

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2.8 Structural changes in Collembola populations following replanting of birch forest with spruce in North Norway

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Abstract

The purpose of the present study was to demonstrate possible effects on Collembola populations by changes in tree composition in natural birch forest in coastal North Norway. In the study area (Dønnes, Nordland County) parts of the natural mixed birch forest has been replanted with Norway spruce and Sitka spruce.

Soil samples were collected in June and October 2004. A total of 52 species of Collembola were found (36 in birch, 32 Sitka, 34 Norway spruce). Eighteen species were common to all three sites, while birch had 12 unique species. Nine species from the coniferous plantations were not seen in birch, while Norway spruce and Sitka had only minor differences. The most abundant species were Mesaphorura macrochaeta, Isotomiella minor, Parisotoma notabilis and Megalothorax miniumus which made up 55% of all individuals found. Total abundance averaged on 91,000 (Sitka), 53,000 (Norway spruce) and 32,000 (birch) inds./m^2, with spring densities 40–80% higher than in autumn.

The planting of Sitka/Norway spruce changed species composition but gave no significant reduction in species number, while population densities increased considerably.

Introduction

Afforestation and change of tree species from downy birch (*Betula pubescens*) to conifers like Norway spruce (*Picea abies*) and Sitka spruce (*Picea sitchensis* and *P. lutzi*) have been carried out for more than 100 years in Norway. Today about 15% of the productive forest area within the afforestation area consists of planted spruce. During afforestation in Norway large forest resources have been built up in the coastal areas. In West Norway the estimated annual cutting volume of spruce will amount to 1.6 million m^3 in 2020.

Change from birch to conifers often leads to a decrease in soil pH and base saturation (Mikola 1985, Frank 1994). Effects on the populations of birds and mammals have been reported by Spidsø (1994). However, the consequences for biodiversity in general and ecosystem processes are not well known. Although the composition and abundance of the Collembola fauna in Nordic coniferous and deciduous forests are well documented (Hågvar 1982, 1983, Hågvar & Abrahamsen 1984, Huhta et al. 1986, Axelsson et al. 1984), there are few studies designed to demonstrate the effects of changed tree composition in silvicultural practice. Huhta et al. (2005) compared the changes associated with planting of birch on formerly coniferous ground, but we have no data from the reversed situation – planting of conifers in birch woodland.

Study site

The study site is situated in the southern boreal zone on the west coast of Nordland County (66° 12' N) about 40 m above sea level. Mean annual temperature is 5.6°C, mean annual precipitation is 1,255 mm. The vegetation belongs to the Melico-betuletum (Aune 1973) complex. The soil is classified as a brunisoil. (Agriculture Canada 1987). In 1962 the pH in the A horizon varied from 4.8 to 6.5, and in the B horizon from 5.5 to 6.5.

Both spruce stands were planted in 1953. Several stand parameters from 1999 in the plantations of Sitka spruce and Norway spruce are given in table 1.

Table 1. Parameters from the Dønnes plantations (1999)

Tree species	Site index (H40)	Number n/ha	Basal area m^2/ha	Volume m^3/ha	Height m
Sitka spruce	S23	2,353	76.6	649.5	17.9
Norway spruce	G15	760	38.5	347.0	13.0

Within the sampling plots under the conifers ground vegetation was mostly absent due to reduced light, with the exception of some sporadic mosses and a few higher plants. The open birch forest had a varied ground flora dominated by *Vaccinium* spp., moss and grass. The soil cores (0–8 cm) from conifers consisted of an upper layer of decomposing needles with a rather compact sandy mineral soil in the lower part. In the birch forest the upper part of the soil cores consisted of leaf litter transforming to a turfy organic soil in the lower part (mineral soil only at deeper levels).

Material and methods

In each of the three study sites 25 samples of the soil/litter layer were taken by a soil corer (33 mm diam.) on 2 June and 4 October 2004. The samples were taken in 5 subplots with 5 from each. Each subplot covered an area of about 1 m^2. The subplots were located in areas with a uniform and similar soil/vegetation character, typical of each of the forest types, as described above. Each soil sample was cut in two (0–4 cm, 4–8 cm depth) and extracted in high gradient apparatus until dry (8–10 days, temperature gradually rising from 20–60°C). Pilot sampling indicated that very few individuals penetrated to strata deeper than 8 cm.

Results

Abundance

Total collembola abundance (N/m^2) as an average of the June and the October samplings were 91,000 in Norway spruce, 53,000 in Sitka and 32,000 in birch. The highest abundance was 113,000 in spruce in June and the lowest 23,000 in birch in October (Figure 1).

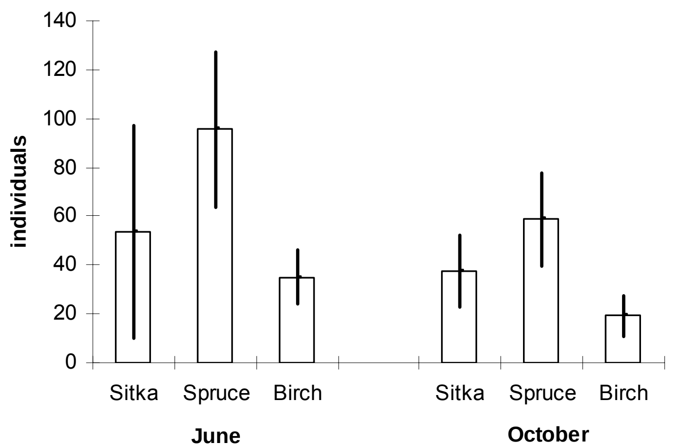

Figure 1. Total abundance of Collembola in June and October. Figures show mean number and standard deviation of individuals in 25 soil cores, each 8.55 cm^2, 8 cm deep.

Although a total of 52 species were recorded, only 16 species had dominance values of more than 5% in the June or the October samples (Figs. 2–3).

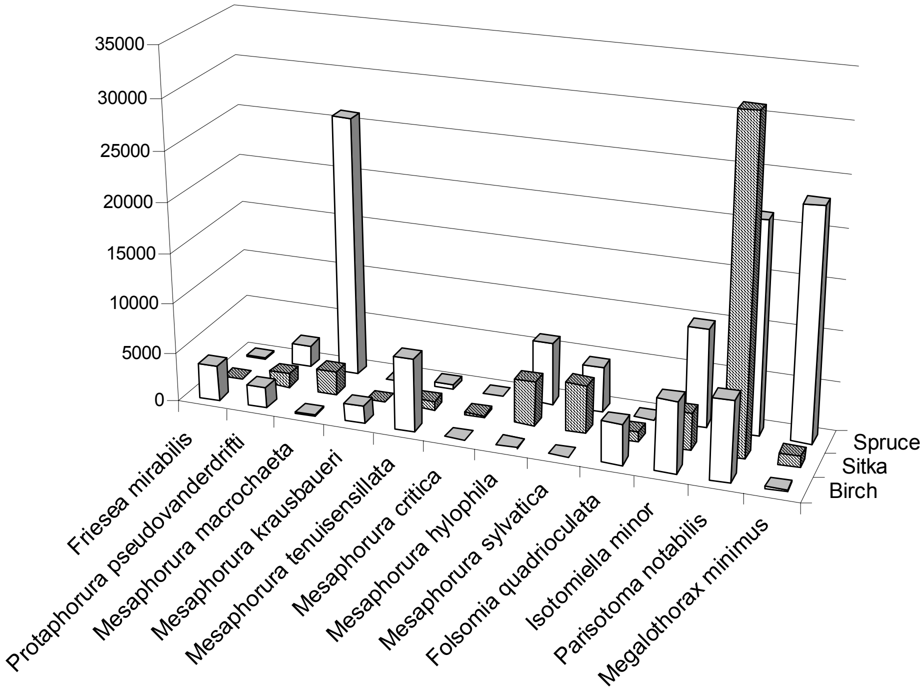

Figure 2. Abundance (N/m^2) of most dominant (>5%) Collembola species in June

Vertical distribution

At the peak densities in June 80–90% of the individuals were in the upper 4 cm. In October the vertical distribution was more even, with up to 30% of the individuals in the 4–8 cm layer in Norway spruce. However, there was considerable variation among genera and individual species. In the dominant species *Isotomiella minor* and *Parisotoma notabilis* more than 90% of the individuals were in the upper 4 cm. Members of the dominant genus *Mesaphorura* penetrated to deeper layers, with 60% of *M. hylophila* below a 4 cm depth. Other *Mesaphorura* were closer to the surface, with 95% of *sylvatica* and *italica* at a depth of 0–4 cm. *M. macrochaeta* and *M. tenuisensillata* were intermediary with 50–60% in the upper 4 cm.

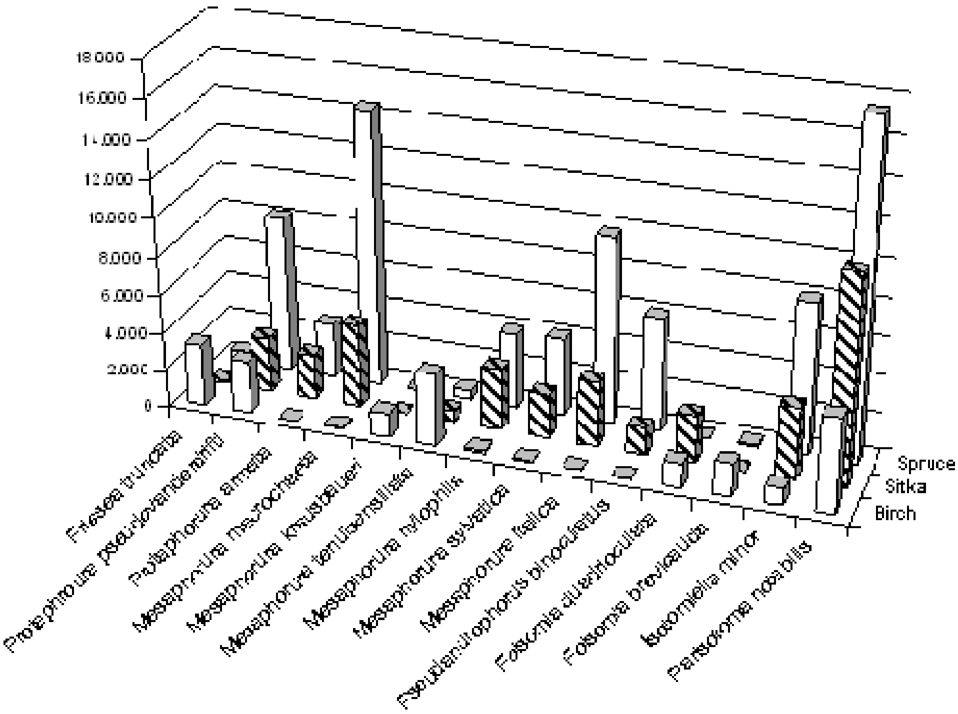

Figure 3. Abundance (N/m^2) of most dominant (>5%) Collembola species in October

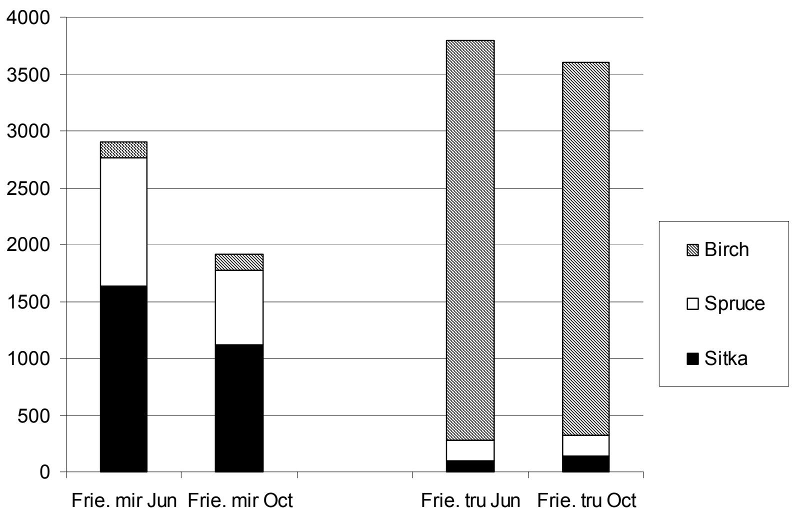

Figure 4. Difference in abundance (N/m^2) and habitat preference of Friesea miab-ilis (left) and F. truncata (right) in June and October.

Site preferences

Apart from clear differences in total abundance among Sitka, Norway spruce and birch, the species composition also differed. A simple comparison of presence/absence revealed that birch had 12 unique species which were not found in Norway and Sitka spruce, whilst Norway and

Sitka spruce both had 3 unique species. Norway and Sitka spruce combined had 10 species not found in birch. When individual species abundances were compared, the differences among the sites became even sharper. Species present in more than one site often differed in abundance data. The two species of *Friesea* clearly differed in their habitat preferences. *F. mirabilis* was most abundant in conifers, *F. truncata* under birch (Figure 4). The various species of the small euedaphic *Tullbergiinae* (*Mesaphorura* and *Paratullbergia*), which made up more than 30% of all individuals collected, were particularly illustrative: *M. krausbaueri* was only found in birch, while *M.critica* and *P. callipygos* were only seen in the conifers. Six species of *Mesaphorura* were found in all sites, but *macrochaeta*, *hylophila*, *sylvatica* and *italica* were dominant in Norway spruce/Sitka, while *tenuisensillata* preferred birch. The odd species *M. jirii* was found in all sites in low abundance. The most abundant species of all collembola, *Parisotoma notabilis*, reached the highest densities under conifers.

Discussion

The observed differences in species composition between the three collecting sites may partly be explained by differences in vegetative cover. The plots under the conifers hardly had any higher vegetation at all, apart form some patches of moss. Conversely, the birch forest had a diverse ground flora of grasses, moss, small ferns and herbs. A number of *symphypleone* Collembola are associated with above-ground vegetation, which explains the presence of *Sminthurinus*, *Allacma* and the unidentified *Bourletiellidae* in the birch forest.

The planting of conifers in former broad leaf forest usually reduces decomposition rates and builds up an increasing layer of acidifying organic litter (Butterfield 1999, Cassagne et al. 2004). The increased abundance of Collembola under the conifers probably related to a more spacious “living room” in the pack of needle litter and the reduced fluctuations in soil humidity and temperature. The drying out of the upper soil layers in an open forest like our birch site is generally considered to have a detrimental effect on collembola populations.

Our results are in accordance with other studies from the Nordic countries. Hågvar (1983) studied the vertical distribution in coniferous soil Collembola in Norway and reported *Mesaphorura italica* and *M.sylvatica* from the upper layers, whilst other *Mesaphorura* penetrated to deeper layers.

Conclusion

Concerning species diversity and abundance, the planting of conifers on areas formerly covered by hardwoods hardly had any negative effects on soil Collembola. Abundance tended to increase while overall species diversity was only moderately reduced. However, there was a dramatic shift in species composition. A number of species were lost and others survived with lowered densities.

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2.9 ICEWOODS: Earthworms in Icelandic forest soils

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Abstract

Earthworms were collected by handsorting from forests on two study sites in Iceland, one in eastern Iceland with Siberian larch *(Larix sibirica)* and native mountain birch (*Betula pubescens*) and another in western Iceland with Sitka spruce (*Picea sitchensis*), lodgepole pine (*Pinus contorta*) and mountain birch. In each tree species 2–5 age classes of forests were studied and as a reference one open heathland in each study site. In the eastern study site 4 earthworm species were identified and two additional ones in the western study site where the number of specimens and biomass was considerably higher. The species were *Dendrobaena octaedra*, *D. rubida*, *Allolobophora caliginosa* and *Lumbricus rubellus* in eastern study site, and in addition *A. rosea* and *Octolasion cyaneum* in western study site. All species have been identified before in Iceland. There was a tendency to decreased number of specimens and in earthworm biomass with increasing age of forest stands and a tendency to higher subsoil C/N-ratio in forests than heathland. An increasing C/N-ratio in subsoil increased number of *D. octaedra* but decreased the number of *A. rosea*.

Keywords: Earthworms, Iceland, forest, afforestation, C/N-ratio

Introduction

Earthworms are among the most important soil organisms due to their size and ability to promote decomposition, nutrient cycling and soil formation. The species diversity in earthworm communities ranges from 1 to 15 species, but most commonly from 3 to 6 species. The dispersal of earthworms is slow and they usually only spread up to 10 meters year-1. Their occurrence is also highly influenced by soil characteristics such as moisture, temperature, pH, soil air and nutrient status such as organic matter and C/N-ratio (Edwards & Bohlen 1996). Because earthworms demand good soil conditions they are considered valuable indicators of soil quality (Muys & Granval 1997). As the optimum temperature for growth of earthworms is 10–20 °C the soil temperature might be a limiting factor in Iceland. On the other hand most Icelandic soils usually have a high moisture and organic matter content and a fairly high pH because of its basaltic origin, which is considered favourable for earthworms.

In Iceland 11 species of earthworms have been identified (Þorvaldsson & Sigurðardóttir 1998). The occurrence of earthworms in Iceland has mainly been studied in hayfields (Guðleifsson & Rögnvaldsson 1981, Sigurðardóttir & Þorvaldsson 1994) where 4–6 species have been identified. Bengtson et al. 1975 studied the general habitat selection of Icelandic earthworms and identified a total of 8 species, of which 5 were in forests. The forest species were: *Dendrobaena octaedra, D. rubida, Allobophora caliginosa, Lumbricus rubellus* and *Octolasion cyaneum.*

Coniferous forests and heathland are considered species-poor communities while deciduous woodlands and permanent pastures are species-rich communities (Edwards & Bohlen 1996). Iceland is almost completely lacking forests, the only natural forest being mountain birch stands covering only 1.1 % of the country (NSLI 2005). Extensive afforestation is being performed and planned in the country in the future. It is of interest to see the ecological impact of this type of land use. Therefore in this study the earthworm population in soils of three planted coniferous species was compared to native mountain birch stands and natural open heathland.

Materials and methods

The present study is a part of the ICEWOODS project studying biological and environmental changes as a result of afforestation in Iceland. This part of the project concentrated on species composition and biomass of earthworms in different age classes of forests as compared to open heathland used as pasture. In each area the earthworm populations in different age classes of stands of conifer plantations and native mountain birch as well as open heathland were studied. The study was performed at two locations with different climatic conditions, but the stands within each of the two study sites were relatively close to each other with similar climatic conditions. The climate at the western study site, Skorradalur, was somewhat warmer with more precipitation than in the eastern study site, Fljótsdalur, which has more continental character. In the eastern study site five stands of Siberian larch, two stands of mountain birch and one open heathland were compared. In the western study area four stands of Sitka spruce, three stands of lodgepole pine, three stands of mountain birch and one of open heathland were compared.

Earthworm collections were carried out twice on each study site, in early and late summer. In the eastern study site collection was undertaken from11–13 June and 12–14 August 2003. In the western study site the collection was from 18–21 June and 18–22 August 2004. Three samples were taken along five randomly distributed lines in each stand, the lines used for botanical study. In order not to disturb the botanical study the earthworm sampling was placed ten meters uphill from the lines. Thus 15 soil samples were taken in each stand, 30x30 cm wide down to 40 cm depth. Earthworms were collected from the samples by hand sorting on the site and stored in 70% isoropanol at 4 °C for later identification, length measurement and dry weight determination. Identification and nomenclature were based on Stöp-Bowitz (1969). Biomass was determined after drying at 70 °C for 24 hours. Data were calculated separately for the eastern and western study areas by regression analysis using the Genstat program (Pyne et al. 1993) on number of species, number of specimens and biomass collected.

Results and discussion

There was no significant difference between the early summer and late summer collections regarding number of specimens or biomass and the means of these two collections are presented. It was noticeable that an extremely high number of specimens (and species) was detected in the oldest age class of Siberian larch, probably because this plantation was located close to old farmhouses and a plant nursery. This age class explains the unexpected high number of earthworms in Siberian larch and is kept separated in the calculations (Table 1).

A total of six species of earthworms were identified in the study, four in the eastern study site and six in the western study site, indicating more favourable conditions in the western study site. The species identified in the eastern study site were *Dendrobaena octaedra, D. rubida, Allolobophora caliginosa* and *Lumbricus rubellus*. In addition *A. rosea* and *Octolasion cyaneum* were found in the western study site (Table 1). All these species have been identified from Iceland before. Apart from *A. rosea* these are the same species as found by Bengtson et al. (1975) in Icelandic woodland. In the eastern study site two and three species were detected in open heathland and mountain birch forest respectively, compared to five and six species in the western study site. Räti & Huhta (2004) found 0–7 earthworm species in natural birch forests in Finland. The number of species collected in the present study was significantly different between tree species only in the western study site ($P< 0.001$), with the highest number in mountain birch and the lowest in lodgepole pine.

The number of specimens collected was significantly higher in the western study site than the eastern site ($P< 0.001$), a result probably related to the better climatic conditions with higher temperature and precipitation in the western study site. No special trend was detected in the number of specimens in different age classes within species in the eastern study area. On the other hand in the western study site there was a decrease in the number of specimens ($P=0.005$) as the stand got older. The number of specimens collected in the western study area was significantly higher in mountain birch than in spruce and pine stands (P< 0.001).

Table 1. Earthworm communities presented as number of specimens on m^{-2} in each forest type.

		Dendrobena octaedra	Dendro-bena rubida	Allolobophora caliginosa	Allolobophora rosea	Lumbricus rubellus	Octolasion cyaneum	Total
Eastern Site	Heath	6.3	3.8					**10.1**
	Birch	6.5	0.7	0.4				**7.6**
	Larch (1–4)	1.1	4.0					**5.1**
	Larch (5)	16.1		81.1		27.4		**124.6**
Western Site	Heath	1.5	1.7	7.0	19.8	4.8		**34.8**
	Birch	1.7	15.9	11.9	13.6	17.6	0.4	**61.1**
	Pine	0.3	0.4	13.6	8.6	2.1	0.4	**25.4**
	Spruce	1.0	0.4	13.7	10.8	3.7		**29.6**
Mean		4.3	3.3	15.9	6.6	7.0	0.1	

Mean of early summer and late summer collection and age classes. The oldest larch stand presented separately.

The biomass was significantly different between age classes in both study areas. As mentioned, the oldest age class of Siberian larch had an extremely high number of earthworms and if this age class is omitted the biomass in the larch stands was of the same level as in mountain birch and heathland and decreased with increasing age of stands. In the western study area the biomass was lower in lodgepole pine and Sitka spruce (P= 0.033) compared to mountain birch and open heathland and in general it decreased as the stand got older (Figure 1).

The topsoil pH (0–10 cm) was between 5.2 and 6.8 and in subsoil (10–30 cm) between 5.7 and 7.1, and was generally higher in the eastern than in the western study site. In the eastern study site the pH was lowest in birch stands and in the western study area in Sitka spruce stands. The pH decreased with increasing age of lodgepole pine stand, but not for other tree species. Compared to open heathland the pH in both topsoil and subsoil decreased both under deciduous trees (birch) and conifers. Increasing pH had no significant impact on number of earthworms but had a tendency to increase the number of *D. octaedra* and *A. rosea*. The C/N-ratio was in most cases below 20, both in topsoil and subsoil, and it increased in forests compared to open heathland, indicating an accumulation of leaf litter with a high C/N-ratio (Figure 1). An increasing C/N-ratio in subsoil increased the number of *D. octaedra* while it decreased the number of *A. rosea* (r = - 0.70**).

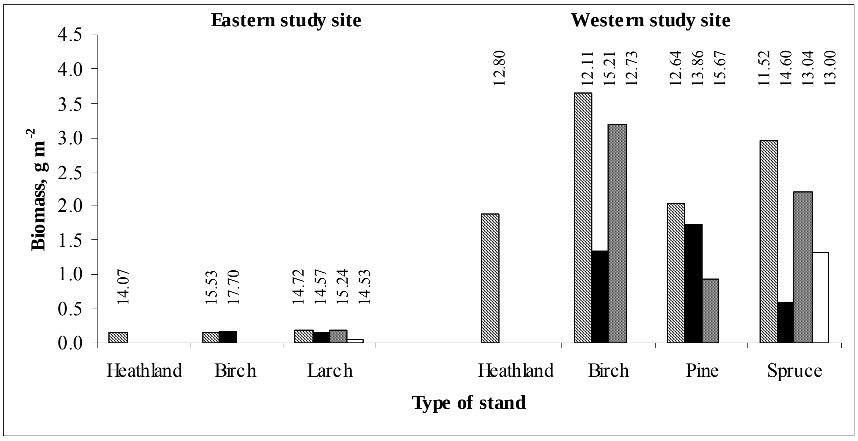

Figure 1. Biomass (g m^{-2} dry weight) in different age classes of stands in the eastern and western study sites. Figures above each column represent C/N-ratio in subsoil.

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2.10 The objectives of the research network “Centre of Advanced Research on Environmental Services” (CAR-ES)

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Introduction

Forest ecosystems provide many deliverables or benefits to society. The most obvious one is wood for the forest industry. Other benefits include berries, hunting, and recreation. More recently recognised benefits are environmental services such as carbon sequestration, water protection and biodiversity, which are without an immediate market value (Figure 1, left side). On the other hand, there are pressures (e.g. climate change, air pollution, exploitation, and costs) on the ecosystem that may hamper the wood production or other benefits (Figure 1, right side).

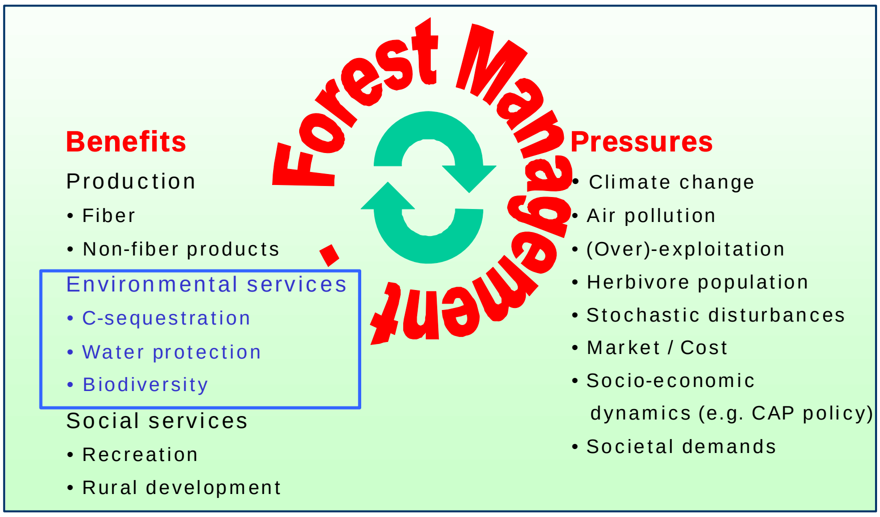

Figure 1. Forest ecosystems are exposed to a series of pressures that may influence or degrade the benefits expected from multifunctional forestry. The goal of sustainable forest management can be seen as modifying or reducing the pressures and optimising the possible benefits. We focus on environmental services.

Forest management has the potential to reduce or avoid pressures and optimise environmental services provided that the underlying mechanisms are known. Ideally, this knowledge will enable management to be tuned to provide valuable wood products and at the same time to sustain or restore environmental services at reduced external pressures. However, there are potential conflicts between sustained wood production and environmental services, as well as among the environmental services. For instance, maximum C storage may compromise biodiversity, and conservation of biodiversity may restrict the extraction of products in part of the forest area. Conversely, it may be possible to solve several problems at the same time if forest management is optimised to reach multifunctional goals.

Most European nations, including all the Nordic countries, have signed "The Helsinki Agreement" in which they have agreed to follow a number of principles regarding sustainable forest management (SFM). Maintenance and enhancement of environmental services are important components of SFM that need to be balanced with other social and economic objectives. To achieve this, new operational knowledge on environmental services is required.

This research network financed by the Nordic Forest Research Cooperation Committee (SNS) will address the question: How will different forest management options and strategies influence the supply of environmental services? The overall objective is to provide the necessary knowledge for informed decisions on forest management with respect to the following major environmental services: carbon sequestration, water protection and biodiversity. Research will focus on how different management options and management strategies in forestry affect environmental services and on how and whether pressures such as climate change, air pollution and exploitation may be modified with management options.

Environmental Services (ES)

Environmental research within forest ecosystems has had a major focus on the impact of pressures such as air pollution or the impact of substantial forest operations such as clear-cutting. The Helsinki process and the concept of SFM have turned the focus also toward research on the environmental benefits, which society now recognises and demands from the forest sector, and which may become a future source of income to forest owners.

Water protection

Forests play an essential role in the protection and maintenance of water resources. Forests filter and remove pollutants from rainwater and dampen the flow of water through the landscape. In general, surface water and groundwater related to forests are considered as being of high quality. Forest management practices, such as species changes, cutting and drainage affect the quality and quantity of water that enters streams, rivers, lakes and groundwater. Pressures like air pollution, climate change and abandonment/afforestation also interact on the quality and quantity of water from forests. We will consider issues like acidification and eutrophication, erosion and leaching of dissolved organic matter as well as water quantity issues. Implementation of the EU Water Frame Directive stresses the importance of water quality and quantity related to forests.

Biodiversity

The Nordic forests are home to roughly 25000 species of animals and plants. The term biodiversity is coupled with some impact by man and at the same time our objectives protect species. Efforts to preserve the biodiversity fall into two categories. One is to incorporate conservation actions into the management and planning of forest production units. The other is to establish forest reserves. As an example, the forest volume used for conservation purposes by the forest enterprises in Sweden amounts to at least 10% of the total volume. This emphasis on the areas outside reserves is unusual in an international context and is developed most fully in the Nordic countries. On the other extreme is, for example, New Zealand with a strong polarisation between intense plantations and a large proportion forest reserves. It is important to evaluate the effects on biodiversity in relation to the effects on forest economy as well as on other ES of the Nordic conservation strategy. The implementation of the EU Habitats Directive / Natura 2000 will have large consequences for Nordic forestry that need to be assessed.

C-sequestration

The forest ecosystem stores significant amounts of carbon in the biomass of trees and in the soil. These soil and biomass stores of carbon are greatly affected by forest management and harvesting intensity through changes in the standing stock of wood and soil carbon dynamics. Following the ratification of the Kyoto Protocol there has been increasing focus on possibilities to sequester more carbon in biological systems and to use wood for energy production. There are many indications that forests sequester carbon from the atmosphere, thereby providing a significant environmental service to society. The ability to mitigate atmospheric CO_2 is therefore an important part in evaluations of the sustainability of various types of forest management. The potential for increased carbon storage relates to management options such as thinning intensity, rotation length, drainage regime, tree species, and silvicultural system (e.g. target diameter harvesting systems vs. clear-cut systems). The emission/consumption of other greenhouse gasses such as methane and nitrous oxide will be considered as well.

Interactions between environmental services

Best management practices to protect water may often have positive impacts also on biodiversity as well, since a large share of forest species is related to wet forests, surface water and wetland habitats in forests. Similarly methods for enhancing biodiversity may include retention of trees along streams and entire stands on wet and moist ground. In these cases one may assume that the effects on water and on biodiversity are positively synergistic. But we do not know if this also has a positive effect on greenhouse gas exchange. There are water protection practices that potentially may hamper biodiversity and C-sequestration, e.g. forest liming to protect surface water from acidification may have a negative effect on biodiversity and may stimulate mineralisation and thus the release of CO_2. Changes in agricultural policy, especially in the EU member states, may lead to abandonment or afforestation of large areas on former highly manipulated agricultural soils. This gives new challenges on how to acquire or even optimise benefits to water biodiversity and C storage on this new forest land.

Objectives

Research on environmental services in relation to 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 economic and social objectives. The general objectives of the CAR-ES network are to strengthen and develop networking and collaboration among leading research capacities in the Nordic and Baltic countries and to develop and initiate innovative research and development with the focus on identifying, developing and promoting the best practices in forest management for C-sequestration, water protection and biodiversity.

It is not the aim to carry out detailed research within each of these three vast research fields. The aim is to focus on the interactions and the major gaps in knowledge from a holistic view where information can be integrated across the fields. More specifically the objectives are:

- To strengthen the knowledge base for counting and optimising environmental services in SFM.
- To quantify the environmental impact of different management strategies and practices in operational ways which can support decision-making.
- To improve the knowledge and visibility of the environmental services provided by forests among the public as well as among forest owners and managers.

The ambition is to integrate and synthesise the knowledge base (conceptually, qualitatively and quantitatively) on environmental services to the level needed for developing a decision support system (DSS) for SFM. This knowledge base for a DSS may then be implemented by the partners in their internet-based dissemination platforms that may target forest owners and decision-makers as well as the general public.

Follow the development of the CAR-ES or get involved at www.nordicforestry-cares.org

2.11 Native willows (*Salix spp.*) in restoration – a technical solution with ecological and social fidelity

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Abstract

Due to increased anthropogenic disturbances in alpine areas assisted recovery has been proposed as a management strategy in future landscape planning. The intention of this study has been to integrate scientific and applied approaches of restoration by using cuttings from native willows. The study area is situated in the Dovre Mountains, central Norway, in a military training area that will be closed down and has had severe landscape and ecosystem disturbances.

Greenhouse propagation of common, native willows can fulfil the need for plant material in large-scale vegetation establishment in the study area. Planting of willows fulfilled several ecological, political and aesthetic goals that had been expressed for future management of the study area, like use of native species and immediate effects of restoration action. Willow cuttings can be a good restoration method at leeward sites with stable snow layer during winter, and with a particular need for immediate and visual results. The mutual benefits from the scientific and applied traditions of restoration were evident in this project, and this experience can be used in future projects of assisted recovery.

Keywords: alpine, landscape, management, restoration, *Salix* spp.

Introduction

Anthropogenic disturbances in alpine areas are increasing and span a wide range of scales, from small spots up to large landscapes (Forbes 1996, Forbes et al. 2001). Slow recovery rates in alpine areas have raised the question of considering assisted recovery as a management strategy in future landscape planning.

Ecological conditions in the disturbed sites are essential for the possible outcome of recovery. However, successful restoration requires an expanded approach including also technological, social, political, economical, and aesthetic considerations (e.g. Edwards et al. 1997, Hagen et al. 2002). This expanded approach is used in the development of a method for large-scale restoration by greenhouse propagated willow cuttings.

Willows are known to be easy to propagate as cuttings (Chmelar 1974, Hagen 2002, Hartmann et al. 2002) and some experience of using willow cuttings for restoration exists (Houle & Barbeux 1998, Miller et al. 1983, Nordberg et al. 1998). A cutting is a vegetative part separated from a mother-plant, which under certain environmental conditions forms roots (Hartmann et al. 2002). Once a cutting has developed roots it is able to support itself with available water and soil minerals. By using a variety of species and treatment combinations it is possible to deduce appropriate methods for restoration of sites with different characteristics (Jorgenson & Joyce 1994).

Prior to the main project an experiment using fresh willow cuttings for restoration was conducted in the study area. Fresh cuttings of *Salix glauca*, *S. lapponicum*, and *S. phylicifolia* showed high rooting capacity (Hagen 1992). However, the method failed due to very slow growth rates during a period of 10 years (personal observation), and the need for an improved method was evident.

Material and methods

Study area

The study area is situated in the low alpine vegetation region in the military training area called Hjerkinn Firing Range, at Dovre Mountains, Central Norway (63°N, 10°E). Annual precipitation is 450 mm, mean summer temperature (May to September) is 7.2°C, and length of the growing season (number of days with an average temperature of ^{3} 5°C) is 115 days. Coarse, calcium-poor glacial sediments dominate in the area, and vegetation is characterised by lichen and dwarf shrub heaths, Salix spp. meadows, and scattered bogs and fens (NIJOS 1999). The dominating willow species are *Salix glauca*, *S. lapponum*, and *S. phylicifolia*.

Military activity in the area has existed since 1923, but in 1999 the Norwegian Parliament decided to close down the firing range and to "restore the area in a way that entails considerable profit for the natural environment". A long time-scale for restoration is stressed in a Development Plan for the area, and the main goal is to bring at least a part of the area back to an "original state", but the need for some immediate results is also stated. Introduced species will be totally prohibited in the restoration.

Greenhouse cultivation of Salix phylicifolia cuttings

One-year old branch-tips of *S. phylicifolia* were collected in the firing range in December 1997, stored at 1°C in polyethylene bags for two months, and then divided into about 7 cm long cuttings. The cuttings were placed in organic peat soil at 21°C and 18 h daylight (procedures according to Hartmann et al. 2002). During a six-week period 75 % of the cuttings developed roots. During March and April the cuttings had marked apical growth, and top twigs were sheared twice to promote lateral branching. At the beginning of May 1998 greenhouse temperature was gradually lowered to 8°C and plants placed outdoors for hardening. At the end of June 3000 plants were transported to the study area. The cultivated willows were at that time on average 40 cm high with 2–4 branches, and had no catkins.

Field planting of greenhouse-propagated S. phylicifolia

Three localities in 30–40 year old roadsides were selected for small-scale experimental planting in June 1998: Ringvegen, Storranden, and Veslefallet. The localities had 15% vegetation cover, and dwarf shrub heath or willow shrubs dominated adjacent vegetation. All localities are covered with snow in the winter, but one locality (Ringvegen) is more exposed than the other two. At each locality 120 cultivated willow plants were planted in four groups of 30 individuals. Two groups were planted sparsely (2 m distance between all individuals) and two were planted densely (0.5 m distance). In one scarce and one dense group at each locality each plant got 10 litres of organic peat soil filled into the plant hole, while individuals in the other two groups were planted directly into the original soil. Survival and number of lateral branches were recorded for all individuals in August 1998, 1999 and 2000. At the end of the third growing season (2000) five individuals from each locality and treatment were collected randomly for biomass measurements, in total 60 plants.

Four disturbed sites along roadsides were selected for large-scale plantings in July 1998, and planted with respectively 460, 500, 730, and 950 willows. Before planting all sites were covered with a 15–20 cm layer of organic peat soil. An excavator was used to dig peat soil from below the water surface in a small swamp next to the sites. The total amount of peat soil needed was 200 m^3. In total 2640 individuals were planted in irregular rows, at a distance of 0.6 m. In August 1998 and 2000 willow survival was roughly recorded, and the general situation was described with respect to willow vitality, total recovery, and aesthetic landscape evaluation.

Statistical analysis

The Pearson chi-square statistic was used to test the effect of treatments to survival in the field after three growing seasons, and the Kruskal-Wallis non-parametric test for several independent samples was used to test differences in number of lateral branches between treatments (Zar 1996). Two-way ANOVA (general linear model, GLM) was used to test the effects of soil treatment and planting density to number of lateral branches for each locality separately (Zar 1996). Only plants surviving during the entire experiment were included in statistical testing of lateral branching. Simple regression was used to outline the relationship between number of lateral branches and the destructive measurement of total biomass for *S. phylicifolia*. All statistical tests were performed using SPSS version 10.0 for Windows (SPSS 1999).

Results and discussion

Greenhouse cultivation

Greenhouse propagation and cultivation was a resource demanding technique to get appropriate native plant material for restoration. However, the good prospects of plant production make this a much more promising method than using fresh cuttings. During the greenhouse cultivation period lasting from February to May, it was possible to produce new plants of *Salix phylicifolia* attaining the same size as several year old individuals in the study area.

Survival and growth

In total ≥ 90 % of all greenhouse propagated *Salix phylicifolia* plants, both in the experimental plots and the large scale plantings, survived during three growing seasons and this indicated good prospects for establishing a shrub layer in the disturbed sites. Survival differed significantly between localities in experimental plots (chi-square c2 statistic; $P < 0.001$). When testing each locality separately, peat soil treatment showed a negative effect on survival at one locality (Ringvegen, $P = 0.001$), while plant density had no effect at any locality. The majority of deaths were due to jerking and browsing by muskoxen and sheep immediately after planting prior to ground fastening of roots, as the plants were detached from the ground. Later browsing did not detach plants, but seemed to increase lateral branching, as also shown by Tolvanen et al. (2001) and Bergmann (2002).

Simple regression showed a close relationship between number of lateral branches and total biomass ($R2 = 0.655$), and only results for number of lateral branches are presented. Number of lateral branches per plant differed between localities (Kruskal-Wallis; $P < 0.001$), with the highest number of branches in Veslefallet and the lowest number at Ringvegen (Figure 1). When testing each locality separately, peat soil treatment showed a negative effect to number of branches at Ringvegen, and there was a significant interaction between peat and density at Veslefallet (Table 1). Catkins were observed in the plots, but not quantified.

Adding peat soil was expected to have a positive influence on the development of *S. phylicifolia*, as a slightly acid environment is reported to favour rooting and growth of cuttings (Hartmann et al. 2002). The peat had other physical characteristics than the original soil at the sites, and peat on top of the original soil created a barrier for water transport between soil layers with different capillary conductivity (Bradshaw & Chadwick 1980). At Ringvegen this probably caused water deficiency and reduced growth. A possible long-term positive effect of peat soil can only be verified by further observations during subsequent growing seasons, and explicit soil water measurements. The total quantity of peat needed for the coverage of large-scale sites was huge, and the visual impression of the disturbed site was immediately moderated due to the similar colours of peat and the surrounding vegetation. A main obstacle against top soil application in large sites is availability without causing new damage to the area.

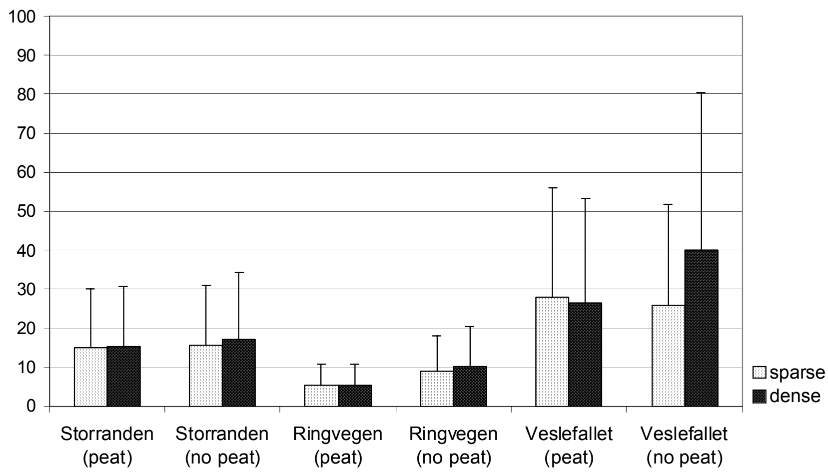

Figure 1. Number of lateral branches for each Salix phylicifolia (mean +/- 1 SE) after three growing seasons for each locality and treatment (with and without added peat). Planting distance is indicated as sparse (2 m distance) or dense (0.5 m distance).

Table 1. ANOVA (GLM) testing the effects of plant density and peat soil treatment to the development of lateral branches in *Salix phylicifolia* after three growing seasons in the field.

Source of variation	Storranden			Ringvegen			Veslefallet		
	df	MS	F	df	MS	F	df	MS	F
Density	1	37.41	0.83 ns	1	480.29	29.68 ***	1	864.74	2.79 ns
Peat	1	31.01	0.69 ns	1	9.23	0.57 ns	1	1071.8	3.46 ns
Density x Peat	1	14.01	0.31 ns	1	10.09	0.62 ns	1	1568.2	5.06 *
Error	116	45.08		105	16.18		100	309.83	

Asterisks behind F-ratios indicate P-values: ns (P > 0.05), * (0.05 ≥ P > 0.01), ** (0.01 ≥ P > 0.001), *** (P ≤ 0.001).

Planting density had no effect on survival, branching, or biomass. At the end of the experiment there was no above- or below-ground contact between neighbouring individuals in the experiment plots. Effects of planting distance can perhaps be expected as individuals get larger and root distribution increases (Callaway et al. 2002, Onipchenko et al. 2001). Practical experience from other alpine willow plantings indicates slow growth during the first 4–5 growing seasons, and then accelerated aboveground growth (e.g. Rytter 2001). Size of disturbances and planting density are crucial to the economic costs of this method, as the actual number of willow plants is an essential part of total cost for a restoration enterprise.

At the most exposed sites insufficient snow cover during winter and soil drainage during summer likely contributed to less development of branches. The experiment showed that these sites were too exposed for the willows, and it seems that this method is suitable in leeward sites with a stable 20–30 cm thick snow layer during winter.

Implications for management

Mutual benefits from scientific and applied traditions of restoration were evident in this project. Engineers and contractors have some experience from application of large-scale willow cultivation and plantings in alpine areas in general, but hardly any documentation exists. Ecological and physiological aspects of propagation and general knowledge about monitoring of plant individuals are common scientific topics. This study has shown that it is possible to create a link between these traditions, using restoration by willows as an example, and making this integrated knowledge available in a real management situation.

Planting of willows can be an applicable large-scale restoration method in leeward sites with a particular need for immediate and visual results of restoration. Such needs can be ecologically, politically or socially motivated (see e.g. Hagen et al. 2002, Lackey 1998).

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2.12 ICEWOODS: The effects of afforestation on the abundance of soil fauna in Iceland

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Abstract

The present study is a part of the ICEWOODS project. The abundance of mites and collembola was studied in a chronosequence study of larch and birch in east Iceland. The abundance was found to be highest in the youngest larch stand, and lowest in the oldest larch stand. The abundance of mites was related to shade and percentage of bryophytes, monocotyledons, and non-vascular plants in ground floor biomass. The abundance of collembola was related to %N, %C, C/N ratio and pH. No correlation was found between total ground floor biomass and abundance of mites or collembola.

Keywords: Afforestation, Betula pubescens, Larix sibirica, soil fauna, Iceland.

Introduction

Most of the lowland of Iceland was originally covered with birch (*Betula pubescens*) forests, but since human settlement in the 9th century forest cover has declined from about 25% to 1% of the land cover (Arnalds 1987). The birch forests have to a large extent been replaced by grazed heathland which has to some degree, been replanted with exotic tree species. The only studies on the influence of similar changes on soil fauna in Iceland were done by Óskarsson (1984) and Oddsdóttir (2002). Other studies on soil fauna in Iceland concern different habitats (Sigvaldason 1973, Hallgrímsson and Sigvaldsson 1974, Hallgrímsson 1975, 1976, Sigurdardóttir 1991, Gudleifsson 1998).

Experimental set-up

The study area is in Fljotsdalsherad (65°13'N, 14°82'W) in the eastern part of Iceland and is further described in Elmarsdottir et al. (2007). The study area consists of 5 age classes of larch and 2 of birch, which were compared to grazed heathland (Table 1.).

Table 1. Stand size and the year of planting or protection from grazing.

Stand designation	Type of stand	Area (ha)	Time of planting/ *protection from grazing
H1	Heathland	7.4	
B1	Birch	5.1	1979*
B2	Birch	6.1	1905*
L1	Siberian larch	4.6	1990
L2	Siberian larch	7.2	1984
L3	Siberian larch	9.5	1983
L4	Siberian larch	3.2	1966
L5	Siberian larch	7.3	1952

Data collection

Within each study area were 5 randomly selected study transects, each 50 m long. Soil samples were taken on June 3rd, July 13th and September 14th , 2004. Samples were taken at two randomly selected sites on each transect with a core sampler, 5 cm in diameter and at three depths: 0–5 cm, 5–10 cm and 10–15 cm. As very few individuals were found in the lower depths the 10–15 cm sample was omitted on September 14th and 4 samples per transect were taken at a depth if 0–5 cm (Table 2.). Due to these reasons comparison of soil fauna abundance in different habitats and at different sampling dates was confined to samples from the topmost soil (0–5 cm). Soil fauna were extracted from the samples with a MacFayden high-gradient extractor, using standard methods described by Petersen (1978) and identified to families and subclasses as in Oddsdottir (2002). Collembola will be further identified to species, but no further identification of mites is planned.

Table 2. No. of samples taken on each transect on different dates

Depth (cm)	No of transects	June 3	July 13	September 14
0–5	5	2	2	4
5–10	5	2	2	2
10–15	5	2	2	0

Results and discussion

The abundance of mites in the topmost soil (0–5 cm) was highest in the youngest larch (planted 1990) but reduced steadily as the larch grew older, and the lowest abundance was found in the oldest larch (planted 1952). A significant difference in number of mites was detected between habitats ($F= 5.99$, $p<0.,001$). A similar, but not significant, tendency was seen for the collembola ($F=1.67$, $p=0.15$).

The abundance of both mites and collembola in young birch (naturally regenerated since 1979) was very similar to that of old birch (protected from grazing in 1905). In the birch forests the abundance of mites was similar to that of larch planted in 1983 and 1984, but the abundance of collembola was similar to that of the oldest larch (Fig 1).

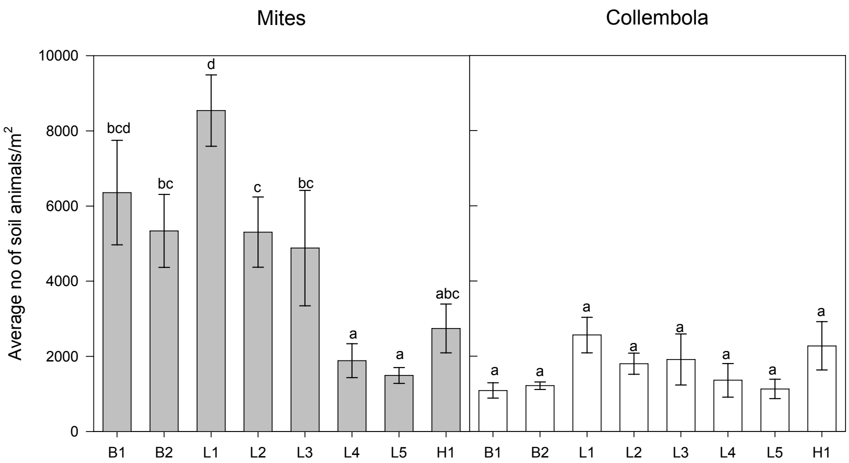

Figure 1. Average number of mites and collembolan/m^2 in the topmost soil of different habitats at all sampling dates. Vertical bars show StE. Columns marked with same letter are not significantly different. Labels for habitats are explained in table 1.

The abundance of soil fauna was highest in the topmost soil (0–5 cm) and few individuals were found in samples from below 5 cm (figure 2A). In the topmost soil, the abundance of soil animals increased during the summer (figure 2B) in all habitats. During the first two samplings (June 3rd and July 13th) numbers of individuals were similar but increased dramatically during the latest sampling (September 14th).

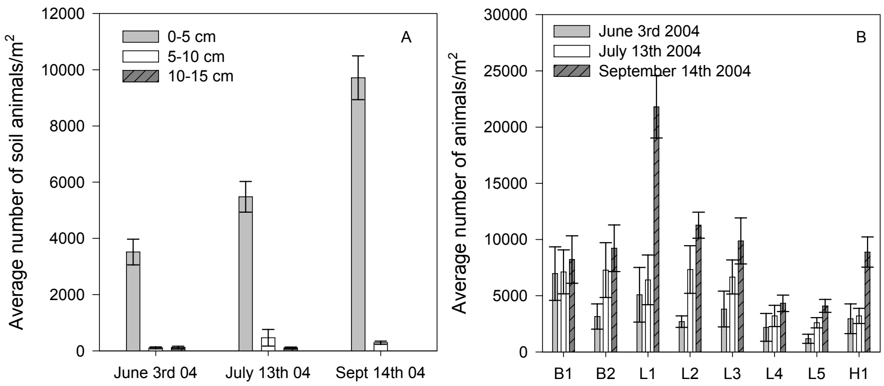

Figure 2. Average number of soil fauna at different depth (A) and in the topmost soil at different sampling time (B)

Table 3. Correlation (Pearson Correlation) coefficient and p value for average number of mites, collembola in relation to different measurements.

	%N	%C	C/N	pH	LAI	Ground floor biomass	% bryo-phytes	% mono-cotyle-dons	% non-vascular plants
Mites	r=-0.25 p=0.12	r=-0.17 p=0.30	r=-0.03 p=0.85	r=0.05 p=0.76	r=-0.55 p<0.001	r=-0.29 p=0.07	r=0.57 p<0.001	r=0.35 p=0.03	r=-0.32 p=0.04
Collem-bola	r=-0.35 p=0.03	r=-0.45 p<=0.01	r=-0.51 p<0.001	r=0.41 p<0.01	r=-0.32 p=0.06	r=-0.18 p=0.26	r=0.031 p=0.06	r=0.23 p=0.15	r=-0.26 p=0.07

There was a significant positive correlation between average number of collembola and %N, %C, C/N ratio and pH but a significant negative correlation between average number of mites and leaf area index (LAI). The percentage of bryophytes and monocotyledons was positively correlated to the number of mites, but negative correlation was between mites and percentage of non-vascular plants (see table 3). No correlation was found between total ground floor biomass and abundance of mites or collembola.

The average number per m^2 of collembola and mites, found in this study, was similar to that of birch habitats in southern Iceland (Oddsdottir 2002) but significantly lower than recorded in larch forest in east Iceland (Óskarsson 1984) and in birch, Norway spruce and Sitka spruce forests in Norway (Fjellberg et al. 2007). The two groups, collembola and mites, seemed to respond differently to the afforestation and to the development of the forest in the subsequent years. No significant differences in the abundance of collembola were found between forests of different ages and types or between forested and non-forested land, whereas the abundance of mites increased significantly after afforestation with larch and then decreased again as the larch forest grew older. A difference in response of collembolan and mite communities has been recorded (Maraun and Scheu 2000), and therefore it could be expected that these two groups of soil arthropods would behave differently. The results of Lindberg et al. (2002) indicate that mites show greater response to disturbance than collembola and it is known that the abundance of collembola fauna can be relatively similar in different forest types (Ojala and Huhta 2001, Huhta and Ojala 2006). Our preliminary results seem to support this but further speculations on the effects of afforestation on soil microarthropod communities must wait for species identification.

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2.13 A novel modelling approach for evaluating the pre-industrial natural carrying capacity of human population in Iceland

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Abstract

A simple approach was used to evaluate the potential human population that the pre-industrial Icelandic environment could sustain. A model was constructed that simulated the population size according to potential biological production available for livestock. Biological production was determined by the extent of the total potential vegetation cover based on the Degree-day concept. Fluctuations in the mean annual temperature cause changes in the potential vegetation cover and as a consequence change the biological production sustaining livestock and ultimately the human population. The simulation's results indicate that the potential population that the environment could sustain during the pre-industrial period fluctuated around 40–80 thousand. The results further indicate that the severe land degradation experienced after the settlement period had a marginal impact on the population size. The pre-historical population did however overshoot the natural sustainability on a few occasions.

Introduction

To increase our understanding of the factors affecting natural sustainability, understanding the past is critical. Iceland is currently facing severe land degradation. It is generally believed that the Icelandic ecosystems have lost half of its vegetation cover and nearly all of its forest cover since the recorded Viking settlement in AD 874 (Thórarinsson, 1961, Einarsson, 1963, Thorsteinsson, 1972, Bergthórsson, 1996). Many factors are likely to have contributed to these changes, such as harsh climate, natural catastrophes, fragile ecosystems and human settlement. Changes in mean temperature are believed to be the largest factor attributed to long term changes in the vegetation cover (Bergthórsson, 1985, Bergthórsson, *et al.*, 1987, Bergthórsson, 1996).

Framework, method and data sources

Theoretical framework

Before the Viking settlement no herbivorous mammals are known to have existed in the Icelandic ecosystems. Hence, it has been suggested that the loss of forest cover due to grazing pressures in combination with a colder climate resulted in an accelerated land degradation and consequently lower CC of the environment to sustain its population (Thórarinsson, 1961, Arnalds, *et al*., 1997). If anthropogenic factors are added to the above CLD analysis (Figure 1), it is clear that increased population and livestock reduces the forest and vegetation cover and may result in accelerated land degradation (Loop R1). Still, the climatic fluctuations, through temperature, either increase the forest and vegetation cover sufficiently to counter the utilisation of the livestock and population or enhance the destruction of the cover.

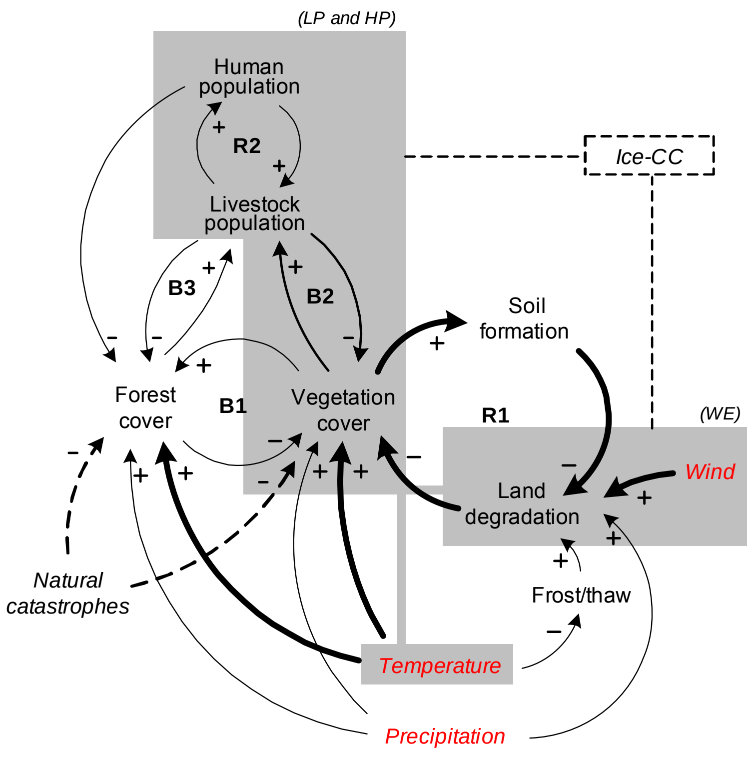

Figure 1: An overview of the integrated natural and anthropogenic factors influencing potential biological production in Iceland. The shaded area shows the parameters used to create the Ice-CC model (carrying capacity) that was used for simulating the natural carrying capacity for human population in Iceland. Vegetation cover model simplified with sub-models; livestock and Population model (LP and HP) and wind erosion model (WE).

Results and discussions

Simulated Carrying Capacity

The simulated results are based on a 30 year running mean with standard deviation (shaded area when shown) from 100 Montecarlo runs. Sensitivity was assessed by varying the input parameters by 10%. This was done for vegetation cover as well as for erosion. The simulations suggest that if all cultivatable land area is used, sustainable as well as yieldable biological productions from the highlands, then the environment could support a human population between 40–80,000 during the pre-industrial period in Iceland (Figure 2). The pre-industrial population in Iceland fluctuated from 50,000 to 60,000, which is within the simulated result of sustainable human population from the Ice-CC, assuming no erosion effects (Figure 3).

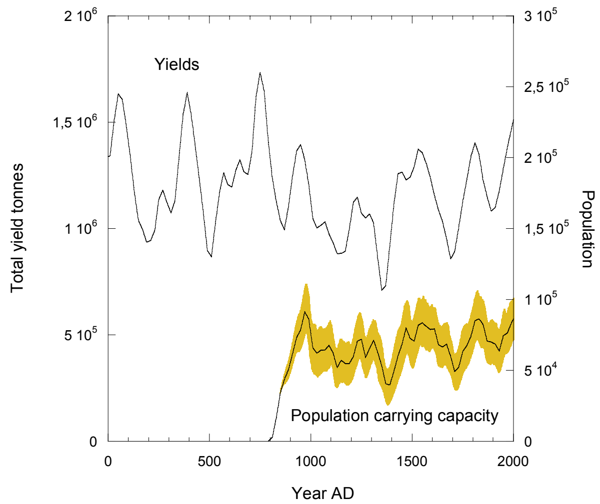

Fig 2: The Ice-CC results on pre-industrial carrying capacity (shaded area is standard deviation).

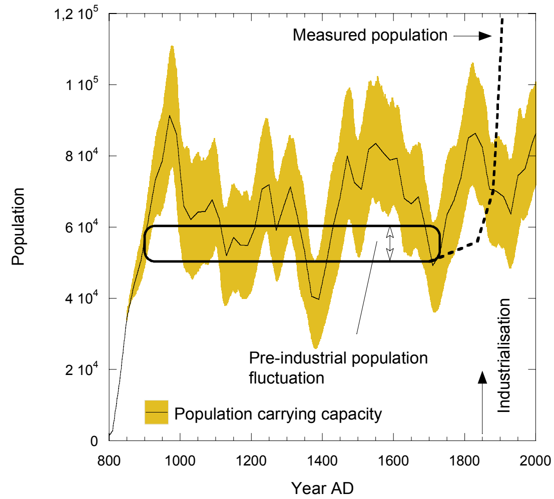

Figure 3: The simulated pre-industrial human population in Iceland

The WE model attempts to recreate historical erosion behaviour. The impact of erosion on biological production is shown in Fig, 4. The impact of erosion on the human population carrying capacity is shown in Fig, 5.

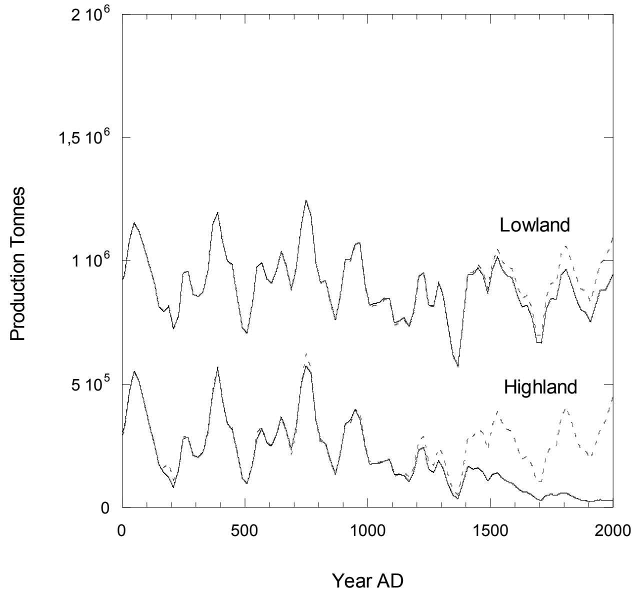

Figure 4: Biological production from cultivatable area from lowlands and usable area in the highlands with the impact of erosion.

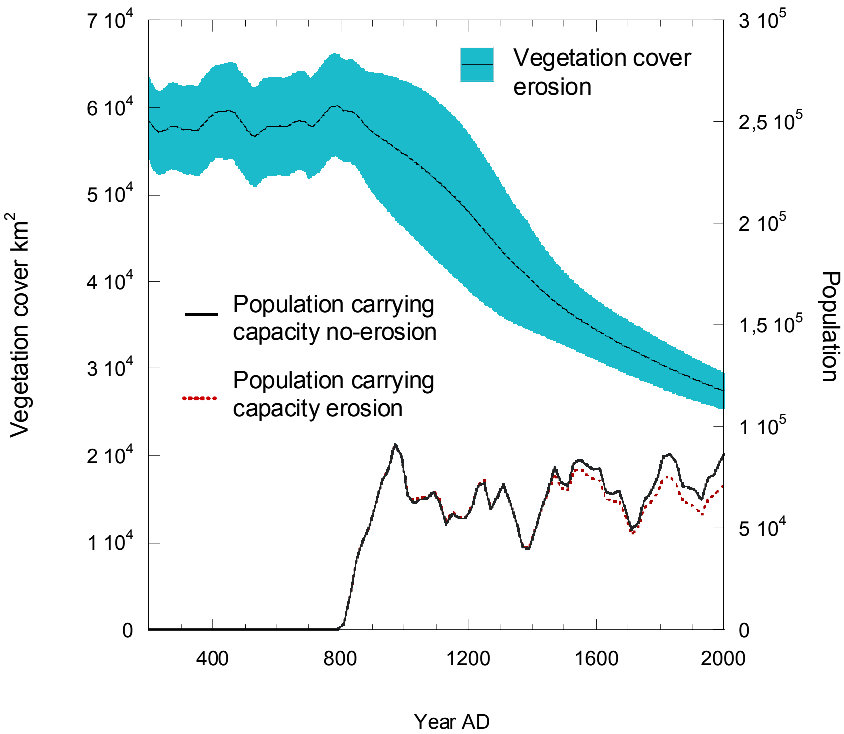

Figure 5: The impact of simulated erosion on sustainable human population is small compared to the declined vegetation cover. Human population in erosion scenario is imposed on population simulated with no erosion.

Discussion

Addressing the question initially stated in the paper, the following can be said; 1) The simulated human population (in the pre-industrial era) in Iceland fluctuated considerately during the last 1100 years and thus the population CC was dynamic ranging, between 40–80 thousand during the period. 2) The impact of land degradation on the population CC is marginal given the assumptions used in the model.

The limitations of the model are twofold; 1) the omission of feedback from livestock population to vegetation cover, and 2) the feedback from vegetation cover to erosion being omitted (see, CLD in Figure 3). This was purposely done, since the model can actually answer the basic questions stated in the beginning without including these mechanisms. Therefore the performance of the model rests on the questions the model is designed around. If more detailed questions are required, e.g. how does livestock contribute to reduction of vegetation cover? or what is the interplay between vegetation and land degradation? the model is not be sufficient to answer that. A modification or a complete new model would be required that is designed to address questions on these levels of details. For answering the basic questions in this study, the Ice-CC model performance ands its accuracy was adequate.

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2.14 Heavy metals and beneficial soil and epigeal organisms of forest ecosystems

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Introduction

Forests, which are one of the main elements of the natural environment, are of great importance for humans. They fulfill a number of crucial functions in the social, economic and cultural lives of people all over the world. At present forests still cover 31% of the land surface (28% in Poland). On the FAO world scale in the years 1961–2001 the area of forests declined by 4.6%. However, in the EU countries the area of forests increased by 11.8%, whereas in Poland since 1945 forest extent has grown by 34%.

The main hazards impacting the condition of forests include abiotic factors (fires, excessive rainfall, droughts caused by a lack of rain, extreme temperatures, strong winds, atmospheric discharges, solar radiation or environmental pollution affecting air, water and soil. All climatic factors mentioned above have been growing stronger and more important recently; however their effect is independent of man. Therefore, having in mind the role of forests, people should strive to limit environmental pollution to alleviate as much as possible the negative impact of this factor on forests.

The present article attempts to follow the effect of metals upon beneficial soil organisms and invertebrates, with particular regard to such microorganisms as fungi and entomopathogenic nematodes which reduce pest populations.

Entomopathogenic fungi

Industrial emissions pose a serious hazard to forests. One of the effects of industrialization is accumulation in forest soils of heavy metals emitted by industry. Unfavourable changes have been also observed in tree healthiness because of decreased biological immunity of forest ecosystems to noxious agents. Numerous scientific papers have revealed that activity of soil micro- and macroorganisms reducing the development of noxious agents declines under the influence of heavy metals.

Beneficial soil organisms that reduce the population of harmful arthropods include entomopathogenic fungi. Studies on the presence of these fungi in forest soils were conducted in Poland. The research revealed their common occurrence in forest ecosystems. Four species of entomopathogenic fungi prevail in the forest soils of Poland: *Beauveria bassiana, Metarhizium anisopliae, Paecilomyces farinosus* and *P. fumosoroseus*. They were isolated from variously used soils, not only forest ones (Mietkiewski et al. 1992) using the trap insect method. Some regularities concerning occurrence of entomopathogenic fungi in forest soils were noted. In Poland *P. fumosoroseus* dominates in the pine forest soil, whereas *B. bassiana* in the litter.

In the studies on entompoathogenic fungi occurrence in forest soil samples from areas of Mediterranean climate the most frequently isolated fungi was *B. bassiana* (Rumine et al. 2005). In this region fungi were also isolated from pine bark samples and there *B. bassiana*, *P. farinosus* and *P. lilacinus* were the prevailing species. Moreover, numerous insects with symptoms of mycoses (fungi induced diseases) were also observed in the forests, where the following species were recognized: *B.bassiana, P. farinosus, P. lilacinus* and *P. javanicus*.

Studies conducted even in an arctic climate (on Greenland) revealed an interesting phenomenon, i.e. a fairly common presence of entomopathogenic fungi. Similarly as in a warmer climate also *P. farinosus, P. fumosoroseus* and *B. bassiana* (Eilenberg et al. 2005) were detected in samples collected in this region.

The entomopathogenic fungi mentioned above constitute a very important biotic environmental agent, particularly through their role in reducing populations of many harmful arthropods in the forests whereas at the same time they do not limit beneficial insect populations. The fungi cause mycoses and kill many development stages of harmful insects (larvae, pupae and imago). Soil is a natural habitat for entomopathogenic fungi. Moreover, entomopathogenic fungi deliberately cultured or as commercial preparations may be applied in traps or into the soil in order to control harmful insects. In this way the chemicals usually negative for the environment may be replaced in forest pest control.

In a forest soil environment entomopathogenic fungi may be liable to stressing conditions which would lead to their reduced pathogenicity towards pests. Specific conditions are necessary in soil for the entomopathogenic fungi to be efficacious. The basic factors affecting fungi comprise moisture, temperature and soil pH. Soil chemical composition is another important agent which modifies fungi pathogenicity.

Due to minimum biodegradation, heavy metals affect the ecosystems including soil fauna. Forest soils in the vicinity of busy roads or industrialized areas reveal high concentrations of heavy metals which influence soil fauna (Gospodarek & Jaworska 1998).

Studies conducted on the impact of industrial pollution, including the effect of heavy metals in soil on entomopathogenic fungi, revealed a great tolerance of these microorganisms to toxic substances (Bajan et al. 1981, Tyrawska et al. 1999). It was found that entomopathogenic fungi have a positive adaptative ability to changing chemical conditions. Laboratory research conducted by Jaworska and collaborations (Jaworska et al. 1998, Jaworska & Gorczyca 2004) demonstrated that only very high concentrations of heavy metals in soil, considerably exceeding the amounts registered even in polluted areas, caused a decline in the pathogenic abilities of entomopathogenic fungi. In such conditions these fungi often totally lost their properties.

Jaworska & Ropek (2000) report that there is a way to prevent a decline in entomopathogenic fungi pathogenicity. The authors revealed the possibility of chemical stimulation of this fungi feature. The method involves addition of magnesium or manganese salt to the culture medium as this causes an increase in entomopathogenic fungi virulence towards harmful insects.

Studies conducted in vitro by Jaworska et al (2000) revealed that magnesium and manganese may also neutralize the effect of such toxic metals as lead, cadmium, zinc and cobalt. It was demonstrated that the interaction of magnesium or manganese applied for in vitro entomopathogenic fungi cultures in appropriate concentrations with metals considered strongly toxic influenced their improved linear and weight growth.

Jaworska & Gorczyca (2004) studied the effect of heavy metals, magnesium and manganese on an important feature of entomopathogenic fungi, i.e. sporulation. Heavy metal ions used for the experiment, including cadmium, copper, lead and zinc, limited fungi sporulation. On the other hand, manganese added to the medium caused an increase in the intensity of fungi sporulation even by 70% in comparison with the control (fungi sporulation in standard culture without heavy metal ions).

The results of studies on the effect of metal ions on entomopathogenic fungi pathogenicity towards insects (Jaworska & Gorczyca 2004) were similar to those for growth and sporulation, namely that the negative in vitro effect of metal ions on pathogenicity was in most cases neutralized by magnesium or manganese applied as a supplement in the culture medium.

This positive effect of magnesium and manganese on entomopathogenic fungi should be used in practice for fungi culturing or for plant protection in the areas where heavy metal contamination is registered.

Biological protection against pests using entomopathogenic fungi has been applied in orchard cultivation. The method proved efficient for controlling numerous pests of fruit trees and bushes. Entomopathogenic fungi of *Beauveria, Metarhizium* or *Paecilomyces* genera may be among others applied for controlling apple sawfly – *Haplocampa testudinea* (Hym.: *Tenthreinidae*). Jaworska (1992) revealed the high efficacy of *Beauveria, Metarhizium* and *Paecilomyces* for this pest control.

Biological preparations based on entomopathogenic fungi should be also applied for protection of forest crops against pests.

Entomopathogenic Nematodes

Another group of beneficial soil organisms which kill harmful insects are entomopathogenic nematodes (EPNs). The greatest importance is attached to entomopathogenic nematodes of the *Steinernematidae* and *Heterorhabditidae* families (Nematoda: *Rhabditida*). The most frequently mentioned species include: *Steinernema carpocapsae*, *S. feltiae, Heterorhabditis bacteriophora* and *H. megidis*.

A natural presence of entomopathogenic nematodes was detected in European forests. In Italy EPNs isolated from pine forest soil were successfully used for controlling many pests (Tarasco & Triggiani 2005) of the following orders: butterflies (Lepidoptera), beetles (Coleoptera), hymenopterans (Hymenoptera) and hemipterans (Rhynchota).

EPNs form a group of natural insecticides which possess many advantages, such as: a wide circle of hosts, ability for fast killing of their hosts, possibility of short culturing and storage of infective material on a laboratory or even commercial scale. However, the most important is that neither the pests become immune to EPNs nor do the nematodes pose any hazard for the natural environment or people and higher animals, as in case of chemical insecticides.

Research on potential use of EPNs for controlling forest pest populations has produced satisfactory results.

Experiments on artificial infection of *Cephalcia abietis* (Hym*.: Pamhillidae*) by EPNs revealed that nematodes are capable of infecting and the efficient killing of, particularly, older larvae (pronymphs) (Jaworska 1993). Still it was demonstrated that the efficacy of EPNs is strongly dependent on soil pH. In highly acid and strongly alkaline soil reactions nematodes proved less effective.

The biological activity of EPNs is modified also by other abiotic factors of the soil environment (Jaworska 1999).

Practical application of EPNs should be preceded by a careful selection of species and strains active in individual environments and against specific pests.

It was found that the activity of EPNs, as in the case of entomopathogenic fungi, may be modified in laboratory conditions. Storing S. feltiae larvae in a manganese solution (concentration 400 mg ·dm-3 Mn (II) caused an increase in pathogenicity towards the test insects used in comparison with the control (nematodes kept in a low-grade formalin solution which is recommended for this purpose) (Jaworska & Gorczyca 2002).

Jaworska et al (1997) found that the *H. bacteriphora* species of entomopathogenic nematodes is very sensitive to contact with water solutions of metal salts. Lead and nickel applied in the experiment very strongly limited the pathogenicity of the nematode species studied in comparison with the control.

The results of research have demonstrated that chemical stimulation of pathogenicity in various EPNs species should be appropriate for dominating nematodes.

Other organisms

Antagonistic fungi are another group of beneficial soil microorganisms, which are capable of reducing development of harmful phytopathogenic fungi causing plant diseases in forest ecosystems. *Antagonistic Trichoderma* fungus is an example.

While studying the effect of selected heavy metals on the growth and activity of this fungus (Jaworska & Dluzniewska 2000) it was found that heavy metals may reduce the activity of these beneficial microorganisms. The authors have reported that fungi response to applied metals depended not only on the concentration but also distinctive differences depending on the fungi species applied.

A wide range of research has been conducted worldwide on the use of mycorrhized fungi which contribute to detoxification of soil and plants. Recognizing the properties of these fungi and their potential application may prove of practical importance for reclamation of soils polluted by industry.

Krupa & Piotrowska-Seget (2000) added a vaccine of pure culture of selected mycorrhized fungi to a cadmium contaminated medium where pine seedlings were cultured. Results obtained in these experiments were most promising. Seedlings in a medium inoculated with mycorrhized fungi were characterized by better biomass growth and survived much longer than seedlings cultured on a sterile medium.

Niklińska & Chmiel (1997) compared resistance to heavy metals in soil bacteria from pine forest humus and observed acquired immunity to metals such as zinc and copper in bacteria originating from regions where high zinc or copper concentrations were assessed in organic matter.

The influence of heavy metals on invertebrates of forest ecosystems is also not without importance. Research conducted on invertebrates inhabiting forest litter contaminated with heavy metals demonstrated that bioaccumulation and biomagnification in food chains depend on many biotic and abiotic factors (Jaworska & Gospodarek 1998). Still, heavy metals present in the environment frequently cause disturbances in the reproduction of invertebrates, lower oxygen demand, growth inhibition through enzyme blockage, replacement of other metals from metal enzymes, inhibition of respiratory chain functions, and changes in membrane permeability.

Studies on changes in populations of pests and beneficial insects under the influence of soil pollution with heavy metals (Jaworska & Gospodarek 2000) revealed certain regularities. Pests were more numerous on plants cultivated in polluted soil, whereas beneficial insects (Syrphidae, Carabidae and Staphylinidae) were far less numerous, with the exception of lady bird larvae.

The influence of industrial emissions on forest ecosystems is a complex problem. Particular attention should be paid to forest emergencies in places where their structure is inconvenient (prevalence of coniferous forests) and where soil is excessively acidified. It was found that heavy metals in soils affect a change in numbers and diversity of macro- and microorganism species. However, microorganisms often reveal a considerable tolerance to pollution or relatively easily adapt to unfavourable conditions and some even efficiently protect forests against the negative effect of pollution and other noxious factors, such as harmful insects and fungal diseases.

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2.15 AFFORNORD – ‘Summing up’ of ecosystem biodiversity sessions. The effects of afforestation on ecosystem biodiversity

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The presentations on Ecosystem Biodiversity have been from a wide spread of north temperate and boreal regions in Scotland, Denmark, Norway and the Eastern United States of America, with most from home ground in Iceland. The taxa examined are fairly comprehensive, including birds, vascular plants, mosses and lichens, fungi, ‘ground arthropods and gastropods’, beetles, collembola and mites, earthworms and soil macrofauna.

The research they document has by no means been easy to accomplish; the data take time to accumulate so answers do not come fast. In particular, some tasks require both skill and time, e.g. on the scale of months to identify collembola, and years before all fungal fruiting bodies appear. Afforestation is a long process in Scotland but substantially longer at Latitude 65^{o} North, particularly if starting from bare ground on high exposure sites. Accordingly, the research into methods of ground preparation and tree planting (together with the role of genetic selection and the use of mycorrhizal symbionts) is important for success in woodland establishment and growth. This is essential knowledge to underpin forest establishment whether it be tree planting or natural regeneration, exotics or natives. In the present studies, because of the long time scales of afforestation, effects on biodiversity must be inferred from differences measured in plots thought to be representative of the various stages in the process (chronosequences).

Given the diversity of circumstances and taxonomic groups under scrutiny, it is not surprising to find variety in the reported impacts of afforestation on biodiversity. One question that came from the audience was “which taxa might best reflect biodiversity?” A recent Pan-European investigation of biodiversity assessed across habitat gradients within individual European states found some evidence of correspondence in the species richness of groups such as higher plants, birds and butterflies associated with the structural heterogeneity of habitats. There were however, some marked exceptions with divergent trends shown by carabids and soil macrofauna (Watt 2003). There are parallels in studies of biodiversity in Britain’s planted forests (papers in Humphrey *et al.* 2003). It follows that, when considering the impact of afforestation on biodiversity, we must examine a variety of taxa because change in one group will not inevitably reflect change in others.

In the presentations here at Reykholt, there was similarly no generic cross-correlation across studies and taxa with respect to the conventional biodiversity indices of species richness or abundance. For example, there was an increase in species richness for fungi but a decrease for vascular plants and birds, associated with tree age over the long-term. Bird studies in Iceland showed different trends to those of songbirds in Scotland, with an increase in both diversity and abundance in the early stages but a major decline during the conifer thicket stage as there was no mass colonisation by scrub dwelling species.

Across all taxa, the most striking effect was in the species composition of communities. With the progression from open country to forest, the vegetation and faunal communities change from those associated with heathland or grassland to those that are viewed as typical of woodlands. Moreover, there were major plant and animal community differences between eastern and western Iceland; almost as much as between native as opposed to exotic tree dominants. The main differences associated with dominant tree species were in more plant species and fungi, and a very different ground fauna in older native birch compared with introduced conifers. The two indices of biodiversity, species richness and the relative abundance of individuals, are not necessarily correlated. In North Norway, collembola populations were larger but less species diverse in spruce compared with birch.

Across studies, there were key stages during afforestation at which biodiversity changed rapidly. Thus the lush ground vegetation following the removal of grazing ungulates and tree planting was associated with increase in plant and bird species. In contrast, biodiversity losses accompanied the heavy shading associated with the next major change – of canopy closure in conifers. The third point of change occurs with the first thinning of conifer stems and the concomitant enlightenment of the woodland interior. As shown by the study of oak thinning practice in Denmark, this is a key stage for woodland communities and is under the direct influence of forest management. The removal of material during thinning prevents the enrichment of forest floor communities with falling debris.

One revelation from the *ICEWOODS* program of studies has been the major influence that introduced organisms might have on those woodland communities that stem from the afforestation of species poor sites. As forests mature the communities comprise a mixture of whatever existing open country organisms can survive or adapt to the new circumstances, together with whatever has been introduced by accident or design, and whatever is sufficiently mobile to have dispersed to the site from afar. In landscapes virtually devoid of mature woodland, there is limited scope for the natural recruitment of species to novel forests.

Biodiversity is heavily influenced by the nature of the afforestation site, the tree species involved, the methods used for establishment and subsequent management such as the age of first thinning. These factors set within the wider regional and national context impinge on the loss of open country species, the gain of woodland species and the impact of introduced species. Novel forests are contrived, as is the richness or poverty of their subsequent biodiversity.

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2.16 ICEWOODS: Changes in communities of ground living invertebrates following afforestation

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Abstract

This project is a defined part of the comprehensive ICEWOOD project. The paper presents some results of the study on effects of afforestation with conifers (Siberian larch, Sitka spruce and lodgepole pine) on ground living invertebrate communities. Thus native mountain birch and open heathland were included in the study to trace the changes. Conifer stands of different ages were studied to see how the communities develop in accordance with the ageing of the stands. There were two study sites, in eastern and in western Iceland.

The results show that afforestation has major effects on ground living invertebrate communities. The fauna of open heathland has very little in common with the fauna adapted to the oldest pine and spruce plantations, pine and spruce having similar effects. The fauna of the withering larch plantations also develops its own character, though having a certain resemblance to the birch fauna. Afforestation seems to have little effect on species richness, nor does it have a marked effect on the productivity of the communities. On the other hand, the species composition is drastically changed.

Keywords: Afforestation, invertebrate communities, species richness, *Betula pubescens*, *Larix sibirica*, *Picea sitchensis*, *Pinus contorta*, heathland, Iceland

Introduction

A comprehensive project, named ICEWOOD, was initiated in 2002 to study the effects of afforestation with conifers (Siberian larch, Sitka spruce and lodgepole pine) on the ecosystems of afforested sites (Elmarsdottir and Magnusson 2007). This paper presents some results from studies on how afforestation affects ground living invertebrate communities. This study is a defined part the ICEWOOD project.

In Iceland there are no previous investigations on effects of afforestation on invertebrate communities. Many studies have been performed under very different conditions in other countries, i.e. countries with much richer fauna, and faunal communities that is specially adapted to woods and forests. Such studies have, amongst other things, shown that in woodlands, carabids are expected to be especially sensitive to the origin, size, fragmentation and age of the habitat as well as the soil conditions (moisture). Spiders are generally more sensitive to structural conditions of the vegetation (e.g. for web placement) and being a very mobile group via ballooning they respond quickly to environmental change (Finch 2005).

The main aim of this study was to see how afforestation affects ground living invertebrates: 1) if invertebrate fauna changes in relation to age of conifer plantations, 2) whether changes are dependent on tree species, and 3) whether woodland invertebrate communities are more productive than those of open land types.

Study areas and methods

Two sites were studied, one in eastern Iceland and one in western Iceland. In the East site eight stands were studied: five Siberian larch stands of different age, L1 being the youngest stand (10 years) and L5 the oldest stand (50 years), two birch stands, B1 and B2 (18 and 97 years, respectively, since preserved from sheep grazing), and a single treeless heathland stand (M1) for comparison. In the West site 11 stands were studied, four Sitka spruce stands, G1-G4 (9–44 years), three logdepole pine stands, F1-F3 (14–46 years), three old birch forests, B1-B3, and one heathland area (M1) for comparison. See Elmarsdottir et al. 2007 for further details on study sites.

Sampling was carried out from mid June to mid August at both study sites. In the East site sampling took place in 2002 and in 2004 in the West site. In each stand, five 2x50 m plots were established randomly. A pitfall trap (72 mm in diameter), which is useful to catch surface active invertebrates, was placed at two random locations in each plot, altogether 10 traps in a stand. Antifreeze (ethylene glycol) was used in the traps to kill and preserve the catch in the East site but 4% formaldehyde solution in the West site. The traps were emptied ca every other week in the East site, but that turned out to be unnecessarily frequent for the purpose of the project, so in the West site 4–5 weeks passed between emptying. In one stand in the West site (G3) the traps were emptied one extra time two weeks before the end of the trapping period. A pathway had been cut along the plots so more light found its way down through the densely planted trees to the ground. However, data from the whole trapping period are used in the analyses.

All the specimens from each pitfall trap were identified and counted, except Acari, Collembola and Nematoda. All adult specimens of Thysanoptera, Lepidoptera, Coleoptera, Araneae, Opiliones and Chilopoda were identified to species. Specimens of Hemiptera, Hymenoptera, Diptera, Oligochaeta and Gastropoda were identified to species when possible.

Specimens that were not identified to species level were excluded from all analyses.

The structure of species occurrence was analyzed by detrended correspondence analyses (DCA), using the PC-Ord program (McCune and Mefford 1999). For analyses, the average number of individuals from the two traps within a sampling plot was calculated. Species data were $\log_{10}(x+1)$ transformed to normalize the distribution prior to analyses.

Results and discussion

Number of species and individuals

In all 34,754 specimens were caught and counted from the pitfall traps. Thereof 25,080 specimens were identified to 299 species. Of the species caught, beetles and spiders were the most common of the surface active arthropods (Table 1). There was also a considerable number of dipterans and hymenopterans, both in number of species and specimens, and were therefore very important groups, although pitfall traps are not made to catch flying insects. The importance of these groups should not be neglected. Given the ability to fly does not mean they are independent of the ground. Most dipterans seek the ground for egg laying and parasitic wasps to find prey in which to place their eggs. This is shown by the fact that the majority of the catch were female specimens.

The number of species in each stand varied from 55 in the oldest pine stand (F3) to 109 species in the young birch stand (B1) in the East site (Figure 1A). Unlike the bottom vegetation (Elmarsdottir and Magnusson 2007) only slightly more species were found in young plantations and birch forests than in closed conifer plantations and species richness had not increased after thinning had taken place (in stands G4 and L5).

The present study indicates that woodland communities are generally more productive than those of open heathland and young plantations. The number of specimens was generally lower in the heathlands and young plantations than in birch forests and older plantations, 20 – 25 and 30 – 40 specimens caught per day, respectively (Figure 1B). A number of studies have indicated that species richness and abundance of arthropods is less in closed forests than in young plantations and open land (Buse and Good 1993, Butterfield 1997), probably due to loss in variety of microhabitats as the bottom vegetation has decreased. However, this does not apply to spiders as they are often more abundant in closed forests (Butterfield 1997), especially web-making linyphiids (Docherty and Leather 1997), as they are sensitive to the structure of the habitat for placing their webs (Finch 2005). In the present study linyphiids were very abundant in the forests.

Table 1. Number of species and specimens identified to species, both from the East and the West site, as well as the total number.

Invertebrate groups	No. of specimens			No. of species		
	East	West	Total	East	West	Total
Insects	**6,715**	**9,425**	**16,140**	**169**	**209**	**253**
Psocoptera	3	2	5	1	1	1
Hemiptera	91	378	469	5	7	7
Thysanoptera	11	20	31	3	3	3
Neuroptera	1	18	19	1	1	1
Trichoptera	4	5	9	3	3	5
Lepidoptera	40	45	85	6	7	9
Coleoptera	1,315	4,207	5,522	29	38	46
Hymenoptera	1,437	2,166	3,603	56	68	85
Diptera	3,813	2,583	6,396	65	80	95
Siphonaptera	0	1	1	0	1	1
Diplopoda	**0**	**14**	**14**	**0**	**1**	**1**
Chilopoda	**0**	**2**	**2**	**0**	**1**	**1**
Arachnida	**2,719**	**5,624**	**8,343**	**27**	**33**	**36**
Araneae	2,129	4,183	6,312	26	32	35
Opiliones	590	1.441	2.031	1	1	1
Gastropoda	**478**	**103**	**581**	**6**	**7**	**8**
TOTAL	**9,912**	**15,168**	**25,080**	**202**	**251**	**299**

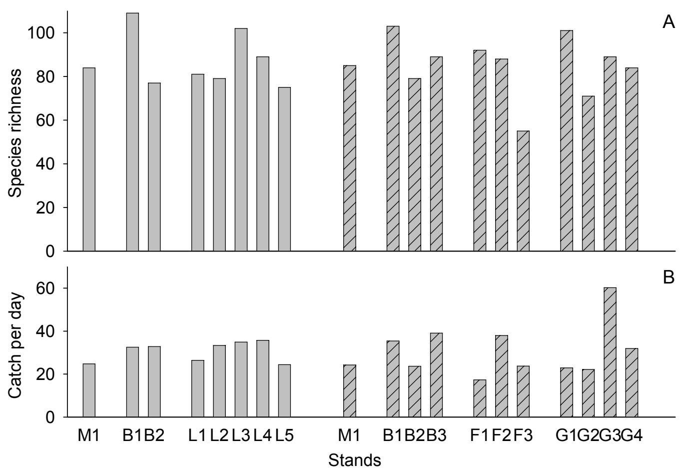

Figure 1. Number of invertebrate species (A) and daily catch of specimens (B) in the 19 stands, heathland (M), birch (B), larch (L), pine (F) and spruce (G), in the East site (grey columns) and the West site (hatched columns).

Community structures

There proved to be a clear difference between the species composition in the East site and the West site (Figure 2) with some species totally restricted to either East or West Iceland. Also, the species composition changed considerably from heathland to the closed pine and spruce stands, with only a few species in common (Figure 2).

Butterfield (1997) indicates that species composition of young plantations differ a lot, both between stands and age of stands, while those of closed conifer forests are very similar both according to age and stand. This is very much in agreement with the results from this study, showing almost no difference in species composition between the older pine and spruce stands. However, the results of Docherty and Leather (1997) indicate a difference in arachnid composition between two pine species. Perhaps a difference in two conifer forests of different ages was not seen in the present study because Iceland is rather poor in woodland arthropods. Also, different arthropod groups show differences in habitat specificity and, furthermore, many species are sensitive to the origin of the land used for plantation (Finch 2005). In the present study both the pine and spruce stands, and actually the oldest larch stand also, were planted in native birch forests.

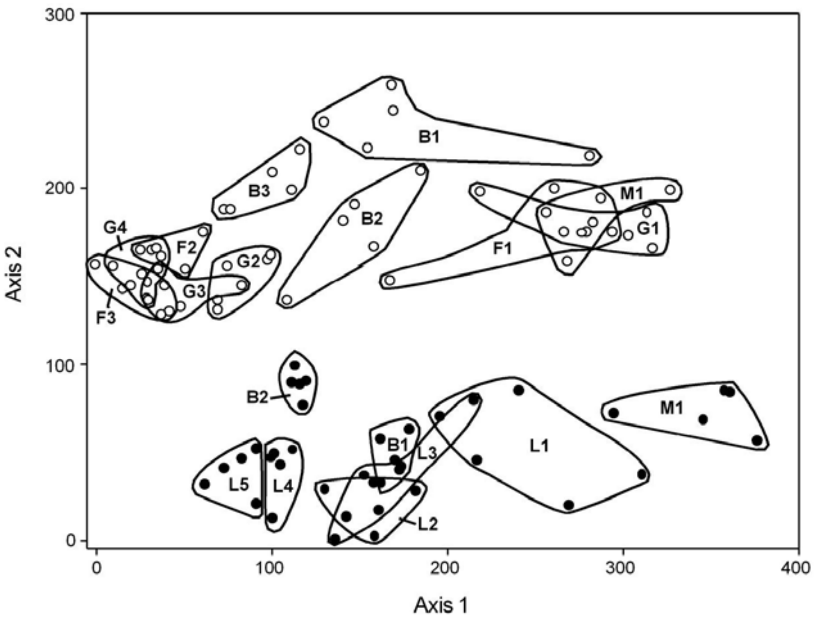

Fig 2. Results of DCA analysis of invertebrate community variation of plots from 19 stands, in the East site (filled rings) and the West site (open rings) areas. The five plots from each stand are encircled. Heathland (M), birch (B), larch (L), pine (F) and spruce (G).

In the present study stepwise developmental changes were indicated, first showing a birch woodland character, then developing its own character as the cover of bottom vegetation decreased (Elmarsdottir and Magnusson 2007). This is in agreement with Butterfield et al. (1995), indicating that species composition of deciduous or mixed forests is in between the closed conifer plantations and open land where conifer trees have been felled. Finch (2005) also indicated a difference in arthropod composition between conifer and deciduous forests.

However, old larch plantations maintain some birch woodland characters, probably because both birch and larch wither.

In the heathland and young plantations the most common species included *Pardosa palustris*, *P. sphagnicola*, *Gonatium rubens*, *Tiso aestivus* and *Oxypoda soror*. The birch forests and larch forests in the East site were similar, with lots of *Patrobus septentrionis*, *Lepthyphantes mengei* and *Lepthyphantes zimmermanni* for example. In the West site species like *Calathus melanocepahlus* and *Mitopus morio* also appeared to be very common in the birch. The oldest pine and spruce plantations were very similar in species composition with rather high proportions of, for example, *L. zimmermanni,* which is a typical woodland species found in undergrowth and needle litter (Docherty and Leather 1997), *Diplocentria bidentata*, *Nebria rufescens* and *Patrobus atrorufus*.

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2.17 Long term benefits of mycorrhizal inoculation of forest tree seedlings

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Abstract

Afforestation is often hampered by high mortality and slow growth rates of forest tree seedlings. One possible reason for this is lack of mycorrhizal symbionts for the transplants directly after outplanting.

In order to test this hypothesis, one year old container grown *Pinus contorta* Loud. and *Larix sibirica* Ledeb. seedlings were planted in a new afforestation area in Southern Iceland. Forest soil inoculum and commercial mycorrhizal inoculum were used as sources of mycorrhizal propagules.

After the first growing season, the number of plants with mycorrhiza was lowest among control plants of both species and highest among soil treated plants. Initially no differences were detected in plant survival, but soil treated pine seedlings grew slightly better than control plants. In the long run, treated plants survived better than control plants, particularly those treated with forest soil. Furthermore, pines survived much better than larch seedlings.

The results indicate that afforestation projects in Iceland may benefit from inoculating young forest seedlings with mycorrhizal fungi. In addition, commercial mycorrhizal products could be improved, perhaps by incorporating more fungal species and other beneficial soil organisms that occur naturally in the forest environment but may be lacking in afforestation areas.

Introduction

Afforestation can be hampered by lack of suitable mycorrhizal symbionts for tree seedlings immediately after outplanting (Haselwandter & Bowen 1996). This is because most tree species are dependent on mycorrhizal fungi for nutrient and water uptake. In Iceland, where large areas have been treeless for centuries, symbiotic fungi may have to spread large distances to reach new plantations. Mycorrhizal propagules are in some cases unintentionally transmitted with transplants into the field, but usually nothing is done to promote mycorrhiza formation of seedlings in tree nurseries. As a consequence, mycorrhizal colonization is usually slow and sporadic in young plantations.

This study investigates whether survival and growth of transplants are affected by inoculation of mycorrhizal fungi in a new afforestation area.

Methods

One year old container grown *Pinus contorta* and *Larix sibirica* seedlings were planted in a new afforestation area in Southern Iceland with and without mycorrhizal propagules in the form of soil inoculum or commercial mycorrhizal inoculum. The soil inoculae came from old stands of pine or larch and commercial inoculae contained *Suillus luteus* for pine and *Suillus grevilleii* for larch. Inoculation was done during planting by mixing 100 ml of inoculum into each planting hole. Rows of ten plants of each treatment were randomly arranged in a block, repeated ten times in ten blocks. At the end of the first growing season, randomly chosen plants, one from each treatment and block, were excavated and their root systems examined for the presence and frequency of mycorrhizal root tips. For the first two years, growth parameters of all plants in the experiment were measured. After 12 years from planting, the plants were surveyed again and the long term benefits of the inoculation treatments evaluated. Treatment effects within species were tested by analysis of variance and means were compared by Tukey's method (a=0.05). Statistical analysis was carried out by SPSS, version 13.0 (SPSS 2004).

Results

At the end of the first growing season there were few mycorrhizal root tips (0–10%) and their numbers did not differ significantly among treatments. However, the number of plants that had any mycorrhiza at all was lowest among control plants of both species and highest among plants which received soil inoculum (Table 1).

Initially plant survival was not significantly different among treatments. In the twelfth growing season, however, plants treated with either source of inoculum survived better than control plants (Table 1). Survival of larch was much lower than that of pine and all larch plants in the control had vanished (Table 1).

Plant height didn't differ significantly among treatments until the second growing season. At the end of this season pine seedlings receiving soil inoculum grew significantly taller than the control plants (Table 1). Furthermore, in the twelfth season soil treated plants were significantly taller than plants treated with commercial inoculum (Table 1).

Table 1. Plant survival, height and relative numbers of plants with mycorrhiza.

Tree species	Treatments	Mycorrhizal plants 1st year (%)	Plant height 2nd year (cm)	Plant height 12th year (cm)	Plant survival 12th year (%)
Pinus contorta	Control	40	8.7 ±0.3 **a**	88 ±19 **ab**	17.8 ±6.2 **a**
	Commercial inoculum	50	8.9 ±0.2 **ab**	79 ±8 **a**	42.2 ±4.6 **b**
	Soil inoculum	80	9.9 ±0.3 **b**	121 ±5 **b**	56.7 ±6.1 **b**
Larix sibirica	Control	0	13.0 ±0.6	----	0.0 ±0.0
	Commercial inoculum	40	13.0 ±0.6	55 ±18	2.2 ±1.5
	Soil inoculum	60	13.4 ±0.7	64 ±9	12.2 ±5.1

Figures show averages from 10 blocks with standard errors. Averages marked with the same letter are not significantly different (α=0.05). Statistical analysis for larch was not done due to high plant mortality.

Discussion

The results of this study indicate that lack of suitable mycorrhizal symbionts of forest tree transplants may reduce afforestation success. This is in agreement with other studies, showing a benefit of inoculation with mycorrhizal fungi for planted tree seedlings (Enkhtuya et al. 2003; Halldórsson et al. 2000). Furthermore, these results indicate that the commercial mycorrhizal product used in this study could be improved, perhaps by incorporating more fungal species and other beneficial soil organisms which occur naturally in the forest environment but are commonly lacking in afforestation areas.

Plant mortality in this study was probably caused to a large extent by root feeding *Otiorhyncus* larvae (Halldórsson et al. 2000), which are known to be a serious pest in the area. Late spring frosts may also have contributed to the high mortality of larch in this study (Snorrason 1986).

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2.18 Facilitation of afforestation by lupine and plastic mulch in southwest Iceland

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Keywords: Afforestation, facilitation, Iceland, *Lupinus nootkatensis*, plastic mulch

Abstract

Vegetation and soils in Southwest Iceland are highly degraded due to the historic removal of native cover and overgrazing by sheep. Efforts to establish trees have proven difficult in this area of high winds, oceanic salt spray, and nitrogen-poor soils. A vegetation restoration program initiated in 1998 on the Keflavik NATO Base resulted in the establishment of Lupinus nootkatensis and grass cover. We started experiments in 2002 to examine if lupine or black plastic mulch facilitates colonization by Sitka spruce (*Picea sitchensis*), Hooker willow (*Salix hookeriana*), and native birch (*Betula pubescens*) by ameliorating microsite conditions. After two year's growth, spruce, willow, and birch seedlings were all significantly taller in lupine than in control plots. Seedlings planted into excavated depressions within lupine exhibited an additional height increase for each species. Black plastic mulch resulted in an increase in height of willow seedlings only. Survival of spruce and birch seedlings was lower where lupine cover was accompanied by dense grass cover. For successful afforestation in Southwest Iceland, we recommend that a mix of tree seedlings be transplanted into lupine stands, preferably in depressions and in sparse grass cover. Hooker willow shelterbelt establishment may also be facilitated by black plastic mulch.

Introduction

Human activities since the settlement of Iceland 1100 years ago have resulted in soil erosion and desertification of large areas (Magnússon 1997). The Sudurnes Peninsula of Southwest Iceland is an area of strong winds that has lost much of its original topsoil. Today, most of Sudurnes is semi-barren or has a low cover of moss or heath. For several decades, Nootka lupine (*Lupinus nootkatensis*), introduced from Alaska, has been widely and successfully used for revegetation of desertified lands in Iceland (Arnalds & Runolfsson 2004). At the international airport on the Keflavik NATO Base, a vegetation restoration program initiated in 1996 has resulted in establishment of several hundred hectares of Nootka lupine and grass cover. We initiated experiments on the Keflavik Base in 2002 with the hypothesis that lupine cover will facilitate colonization by tree seedlings. Lupine improves sites for seedling establishment by nitrogen fixation, addition of organic material, and amelioration of microclimate (Magnússon et al. 2004). For our experiments, we chose Sitka spruce (*Picea sitchensis*), Hooker willow (*Salix hookeriana*), and native downy birch, which have all shown potential for afforestation in trials in Southwest Iceland.

Aradóttír (2004) found that Nootka lupine may have competitive as well as facilitative effects on tree seedling establishment of downy birch in Iceland and that the competitive effects will increase over time as lupine cover expands. Our experiments were initiated to exploit a window of opportunity to plant tree seedlings while the lupine-grass meadows on the Keflavik Base were relatively young and open. In addition to lupine facilitation, the effects of plastic mulch as a method of tree seedling establishment were examined. In experiments by the Iceland Forest Research Service (IFRS), plastic mulch has benefited establishment (Sigurgeirsson 2000). The plastic inhibits competition from herbaceous cover and ameliorates the problem of frost heaving.

Materials and methods

The Keflavik NATO Base is located in the southwest corner of Iceland on the Midnes Peninsula at the tip of the Sudurnes Peninsula. The climate of the Sudurnes Peninsula is moderated by the Gulf Stream and can be characterized as temperate, maritime, and windy. At the Keflavik International Airport, mean January temperature is 0^{o}C, mean July temp-erature is 10^{o}C. Mean annual precipitation is 1074 mm, dispersed throughout the year. The mean wind speed is 6 m/s, with extreme winds to 39 m/s.

Five sites at the NATO Base with patches of lupine of varying density were chosen for experimental afforestation plots. In June 2002 seedlings of one-year Sitka spruce, two-year spruce, downy birch, and Hooker willow were transplanted in adjacent blocks within: (1) non-lupine cover as control; (2) lupine cover; (3) depressions in lupine cover; (4) depressions in non-lupine cover; and (5) black plastic mulch. Containerized seedlings (150-ml for willow, 100-ml for others) were transplanted with a Finnish Pottiputki planting tube. A teabag of RTI Silva-Pak slow-release fertilizer was inserted next to each plant via the tube. This fertilizer was found most effective for tree seedling establishment in trials in South Iceland (Óskarsson & Sigurgeirsson 2004).

During 20–22 May 2004, seedling plots were scored for survival. Seedling heights were measured to the nearest centimeter at the highest living part of the plant. The effects of the experimental treatments (and site) on height of transplants were analyzed by ANOVA (SPSS v11.0) for each seedling type. Four treatment hypotheses were tested separately: heights of seedlings in (1) lupine > control, (2) depressions in lupine > lupine, (3) depressions > control, and (4) black plastic > control. Differences in percent survival within a species between pairs of sites were analyzed by Mann-Whitney U-tests that compared survival among the species blocks of five adjacent seedlings that were scattered within plots. Analyses were considered significant if $P < 0.05$.

Results and discussion

Survival.

Survival of the tree seedlings varied by site, by species, and by treatment. Survival was ≥ 90% in the majority of site-species-treatment categories. However, survival of 2-yr Sitka spruce was 58–66% within lupine in 3 sites with dense grass cover compared to 98–100% in a lupine site with little grass. Survival of the 1-yr spruce seedlings was significantly lower than the 2-yr seedlings. Birch survival also decreased in thick grass and lupine (20–90%), but willow survival (70–100%) was not affected. Many willow seedlings emerged above the lupine cover.

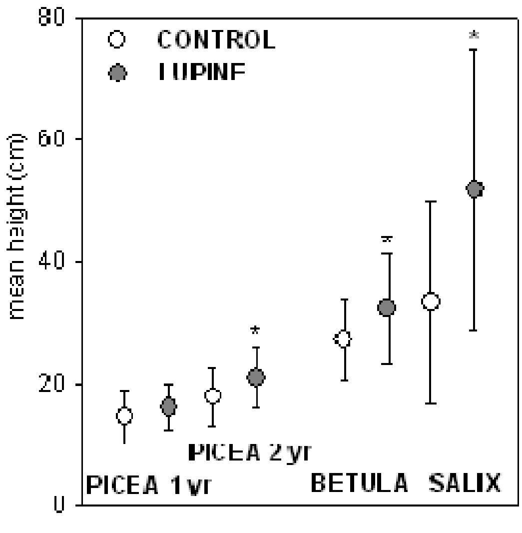

*Figure1. Lupine effect on seedling heights in May 2004. Lines are standard deviations. * = means differ at P < 0.05.*

Lupine effects.

Mean seedling heights in lupine were significantly greater than in control plots for all 3 species (Figure 1). Heights of 2-yr spruce seedlings were taller in lupine than in controls at all sites, even sites with significant mortality. Future years will tell if this facilitated height growth of spruce will allow a number of seedlings to survive long enough to overtop the lupine-grass cover at competitive sites.

It is not uncommon for one plant species to show both facilitative and inhibitory effects on another species, depending upon densities, age, and abiotic factors (Callaway & Walker 1997). In South Iceland experiments, Aradóttír (2004) found that transplanted downy birch seedlings were facilitated by low-density lupine cover compared to barren sites, but survival of birch seedlings was inversely correlated with further increase in lupine density. Birch and Sitka spruce seedlings may fare better if planted in young, open lupine stands, because competitive effects of future denser lupine cover may outweigh facilitative effects. On our study sites where lupine and grass cover has developed a high density, inhibitory effects on survival of Sitka spruce were observed, although the surviving seedlings still showed lupine facilitation of growth. In contrast, Óskarsson & Sigurgeirsson (2004) did not find inhibition by lupine dens-ity on establishment of downy birch and Sitka spruce in a gravelly glacial outwash plain in South Iceland, with better growth (though not significant) in denser lupine. They also reported high survival for birch and spruce seedlings after five years in lupine. At their study site, thick grass has not developed under the lupine stand. This is similar to the cover of the site in our study, where survival of 2-yr spruce in lupine remained 98–100%. These results suggest that dense grass cover is more detrimental to spruce seedlings than dense lupine cover.

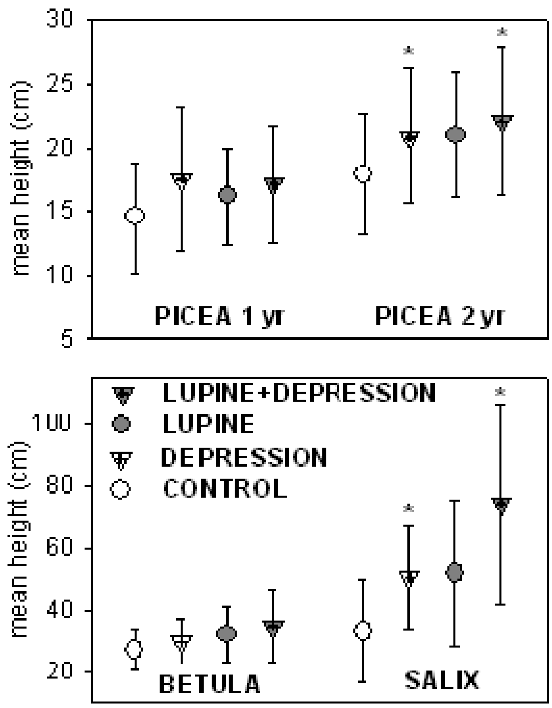

*Figure 2. Depression effect on seedling heights in May 2004. * = means differ at P < 0.05*

Depression in lupine effects.

Mean heights increased significantly for willow and 2-yr spruce where depressions were excavated in lupine (Figure 2). Birch heights also increased at all sites. Both lupine and depression effects were significant ($P \leq 0.01$) for willow and spruce in a 3-way ANOVA on the 3 sites that had depressions both in and out of lupine. From 2003 to 2004, the depression effect decreased relative to the lupine effect (by F values), and thus may become less important as competitive plants expand their cover into the depressions.

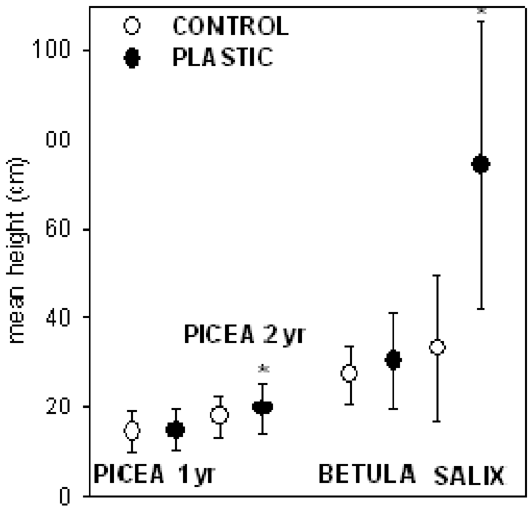

*Figure 3. Black plastic mulch effect on seedling heights in May 2004. * = means differ at P< 0.05*

Plastic mulch effects.

Willow seedlings showed a substantial increase in height with black plastic mulch (Figure 3). Although 2-yr spruce showed an overall significant height increase in black plastic, there was a strong interaction effect (site x treatment). At 2 of 5 sites, mean spruce heights were lower in plastic mulch than in the control. Thus, use of black plastic to facilitate tree colonization showed promise only for willow seedlings. The effect on willow height was similar to that of depressions within lupine (74 cm mean in both).

Black plastic mulch greatly enhanced growth of Hooker willow seedlings, thus should be beneficial in establishment of willow shelterbelts in Southwest Iceland. However, willow seedlings were equally facilitated by planting in depressions in lupine, where the tops of most have emerged above the lupine plants after two years. Treatment by excavations in lupine is less expensive than black plastic mulch for large-scale establishment of willows.

Conclusions

Afforestation in Southwest Iceland may be promoted by transplanting a mix of Hooker willow, 2-yr Sitka spruce, and downy birch seedlings into lupine stands, in depressions where feasible. Grass growth may inhibit seedlings, thus afforestation may benefit from lupine establishment that is not accompanied by grass seeding or heavy fertilizer application. Hooker willow may become the most successful of the 3 species in afforestation via lupine. Willow seedlings were equally facilitated by black plastic mulch, which may be a practical method to create willow shelterbelts.

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2.19 Afforestation of former intensively managed soils

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Abstract

In Western Europe, more and more arable soils are set aside for afforestation. The effect on soil properties can be expected to differ compared to afforestation of marginal soils. However, most studies have been carried out on nutrient-poor soils. The objectives of this study were to investigate changes in soil properties of formerly intensively managed soils. The study was carried out as a chronosequence approach (time for space substitution) to investigate changes during the first 3 decades after afforestation. Seven oak (*Quercus robur* L.) and seven Norway spruce (*Picea abies* (Karst.) L.) stands were selected in the afforestation area Vestskoven, 15 km west of Copenhagen, Denmark. Stand ages ranged from 1 to 30 years. Additionally, a permanent pasture (21 years) located in the study area was included in the study. Soil had developed from calcareous till material and the texture was sandy loam.

This study is also described in the abstract "Changes in soil carbon and nitrogen after afforestation of arable soils with oak (*Quercus robur*) and Norway spruce (*Picea abies*)" in the proceedings of this conference.

The first poster presented results from the mineral soil. It was concluded that during the first three decades covered by the chronosequence study, afforestation changed soil properties derived from intensive cultivation. However, changes in soil properties were generally slow, and at the end of the study period most of the parameters investigated were still closer to conditions found in arable soils than in old-growth forest soils. Furthermore, site conditions inherited from parent material and the former land use seemed to determine the direction and range of changes more than tree species. There was no effect of tree species on C and N storage in the mineral soil. Soil C/N ratios tended to be greater under spruce than under oak, but the difference was not significant.

The second poster presented results from the forest floor. Coherent forest floors had accumulated after ca. 8 years. Obviously, the amount and quality of litter fall had an effect on forest floor properties. There was a higher N storage under spruce than under oak in spite of lower N concentrations in the litter material. This could be explained by the higher accumulation rates of litter material under spruce. Thus, in contrast to results of the mineral soil, the choice of tree species was important, mostly in terms of accumulation rates, N storage, and C/N ratios of the forest floor.

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2.20 Changes in soil carbon and nitrogen after afforestation of arable soils with oak (*Quercus robur*) and Norway spruce (*Picea abies*)

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Abstract

In Denmark, afforestation of arable soils is suggested as an alternative for agricultural land use. However, many environmental consequences are only known from afforestation on marginal or less intensively managed soils. The objectives of the present study were to investigate effects of afforestation with different tree species on former horticultural and agricultural soils. This paper summarizes results on changes in C and N pools in the forest floor and Ap-horizon. The study was carried out as a chronosequence study of seven oak *(Quercus robur* L.) and seven Norway spruce *(Picea abies* (Karst.) L.) stands established from 1969–1997 in the vicinity of Copenhagen. For comparison, a permanent pasture was included. Results suggest that afforestation slowly modifies soil properties. The choice of tree species is less important for the rate of changes than time or land-use history, except for forest floor C and N storage. This is related to the build-up of litter mass, which was higher in spruce than in oak. The most significant changes in C and N concentrations occurred in the 0–5 cm layer of the mineral soil. For the total Ap-horizon, storage of both C and N did not change significantly.

Keywords: Afforestation, carbon sequestration, soil nitrogen, land-use change, oak, Norway spruce

Introduction

In many European countries, the government aims to increase the forested area. The motivations for these afforestation plans are, among others, the surplus of agricultural products, a demand for more recreational areas, biodiversity related to forests, increased C sequestration, and groundwater protection. In Denmark, the government passed a resolution in 1989 to double the forested area within the next 100 years. In this context, afforestation of arable soils as an alternative land-use has been discussed.

Many effects of afforestation on soil properties are only known from studies on less intensively managed soils. It was shown that nitrogen (N) dynamics and organic matter C/N ratios differ significantly between old-growth forest soils and soils that had been subject to afforestation 100 years ago (e.g. Compton et al. 1998). However, the knowledge derived from these studies may not be applicable to present-day arable soils, which differ in N and nutrient status, tillage intensity, plow depth, etc. Carbon (C) sequestration in growing biomass is regarded as one positive effect of afforestation on arable soils (IPCC 2000), but also the soil C pool may change after afforestation. In a review Johnson (1992) concluded that the reversion of agricultural land to forest usually results in substantial increases in soil C. Soil C pools can be expected to be more resistant to sudden changes in forest management than C pool in the living biomass. Changes in soil C should therefore be included in estimates of C sequestration due to afforestation.

The objectives of this study were to investigate the dynamics in soil C and N pools in the forest floor and the former plow layer during the first three decades following afforestation of intensively managed arable soils with different tree species. It was hypothesized that (i) afforestation would increase soil C and N storage with time, and (ii) changes in soil C and N storage would occur faster under tree species with high growth rates and relatively low litter decomposition rates than those with opposite characteristics. To test these hypotheses, a chronosequence study was conducted as in spruce and oak stands of different age classes. Results presented in this paper are a summary of the data published in Vesterdal et al. (2002) (C data) and Ritter et al. (2003) (N and C/N data).

Material and methods

The study area Vestskoven is located 15 km west of Copenhagen, Denmark (55°70'N, 12°35'E). The climate is temperate with a mean annual temperature of 7.7 °C and a mean annual precipitation of about 600 mm. Vestskoven was established as an urban forest in the vicinity of Copenhagen. Afforestation started in 1967, and today the forest area is about 1340 ha with large openings of permanent pastures in between forest stands. Forest stands (1–10 ha in size) are mainly monocultures of oak (*Quercus robur* L.), beech (*Fagus sylvatica* L.), pine (*Pinus sylvstris* L.), and Norway spruce (*Picea abies* (L.) Karst). Preceding afforestation, the land had been intensively used as arable fields or for nurseries for several 100 years. In addition to the nutrient supply derived from this former land use, current annual atmospheric N deposition is about 14–18 kg N ha^{-1} $year^{-1}$ in mature oak and spruce stands. Hence, soils have a high nutrient content and a high pH (pH_{CaCl2} > 4.6). Soil texture is sandy loam, and soils are rather homogeneous over the area. Only one spruce stand had to be defined as an outlier. The chronosequence study was conducted in seven oak and seven spruce stands, their ages ranging from 1 to 30 years after afforestation. Canopy closure was reached in about 10-year-old stands. For comparison, a permanent pasture (21-year-old) was included. For details on the study site, the soils, and the management of the stands see Vesterdal et al. (2002) and Ritter et al. (2003).

Sampling and analysis

Forest floor and mineral soil samples were collected in September 1998 in three plots in each forest stand and the permanent pasture (mineral soil only). Mineral soil was collected down to the basis of the Ap-horizon using a soil auger with 5 cm diameter and afterwards divided into sub-samples of three depth strata (0–5 cm; 5–10 cm; 10–25 cm). Chemical analyses were carried out on the < 2 mm fraction of the mineral soil. Forest floor material was divided into foliar and non-foliar fraction. Total C and N concentrations in both mineral soil and forest floor material were analysed by dry combustion (Dumas method). Total C and N contents were calculated based on the bulk density determined on mineral soil samples and the dry mass (60 ˚C) of the forest floor material. For details on the experimental design, the chemical analyses, and the statistics used in the study see also Vesterdal et al. (2002) and Ritter et al. (2003).

Results and discussion

Forest floor

Forest floors in the afforestation stands had developed after about 8 years. In spruce stands and the 10-year-old oak stand, more then 80% (dry weight) of the forest floor material was made up of the foliar fraction. In the other oak stands, the mass of the foliar and the non-foliar fraction were equal. Accumulation of forest floor material was significantly higher under spruce than oak: after 30 years, the difference was almost 5 times, with 23 Mg forest floor material ha^{-1} in the spruce stand. This was attributed to differences in the amount and composition of litter fall. An effect of litter quality on decomposition rates has been found by several studies (e.g. Aber et al. 1990; Anderson 1991). While the trend of increasing accumulation seemed to continue under spruce, the mass of the forest floor material in the oak stands had already reached a somewhat constant level of about 5 Mg ha^{-1} after 20 years (Figure 1).

Consequently, C sequestration and N storage were higher under spruce than oak. Accumulation rates of C were 0.36 Mg C ha^{-1} year^{-1} for spruce and 0.08 Mg C ha^{-1} year^{-1} for oak. Thus, there was a significant interaction between species and stand age. Other studies reported a C sequestration in forest floor material at even higher rates (Hamburg 1984; Richter et al. 1999). High decomposition at Vestskoven due to a high nutrient status may explain the lower C sequestration rates. After 30 years, C storage in the forest floor had reached a constant level of about 2 Mg C ha^{-1} under oak. In contrast, 9 Mg C h^{-1} were stored under spruce, and the trend was still increasing. The lower C content in the forest floor under oak may be attributed to the faster decomposition rate of oak litter compared to spruce litter, as also reported by Dziadowiec (1987).

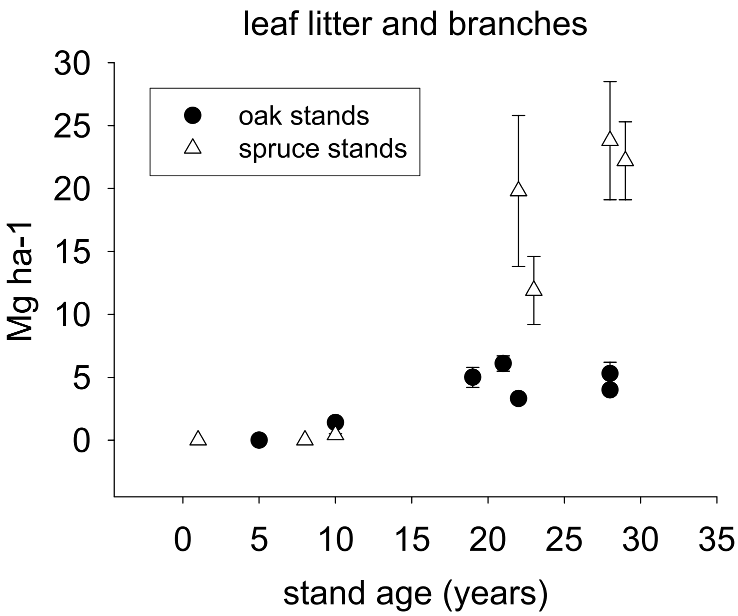

Figure 1: Accumulation of forest floor material under oak and Norway spruce during the first 30 years after afforestation.

N content in the forest floor (both fractions) increased with time, but at different rates for the two tree species. After 30 years, N storage was 5 times more under spruce (~ 300 kg N ha^{-1}) than under oak. Storage was about to level off in oak stands, but was still increasing in spruce stands. It may be assumed that the forest floor in spruce stands may become an important N sink in the forest stands. Nevertheless, N storage in the forest floor of the 30-year-old spruce stand was only 7% of the total N storage per hectare of the upper soil layers, comprising the Ap-horizon and the forest floor.

The C/N ratio of the foliage fraction did not change significantly with time after afforestation, but was clearly affected by tree species choice. Oak stands had on average a lower C/N ratio (22.7) than spruce stands (26.4). These values were clearly lower than those reported from another study on oak and spruce on similar soils of high nutrient status in Denmark, where C/N ratios were > 28 (Vesterdal and Raulund-Rasmussen 1998). Since those sites had been forests for centuries, the different results may indicate the influence of land-use history. Litter quality is found to be correlated with the nutrient status of mineral soils (Chappell et al. 1999). Thus, the lower C/N ratios of the present study are presumably a result of the high soil N capital caused by the intensive management and fertilization of the former arable soils.

Mineral soil

Neither concentrations nor storage of C in the Ap-horizon were affected by tree species. In the permanent pasture, C concentrations in 0–15 cm depth and C storage in both 0–5 cm and 5–10 cm depth were slightly higher than in the same soil layers under forest stands of comparable age. In the forest stands, C concentrations in the upper 5 cm mineral soil tended to increase with stand age. In contrast, they decreased in the deeper soil layers (Figure 2). The same trends were found for soil C storage. Similar patterns in relation to different soil depths are reported by Richter et al. (1999) and Jug et al. (1999). In total, there was no significant change in C storage in the Ap-horizon with time (Figure 3a). It must be assumed that afforestation of nutrient-rich soils in temperate climates does not necessarily result in significant C sequestration in soils within a period of only 30 years. This is in contrast to the recent suggestion that afforestation could result in C sequestration of 50 Mg C h^{-1} over 30 years (Bouwman and Leemans 1995).

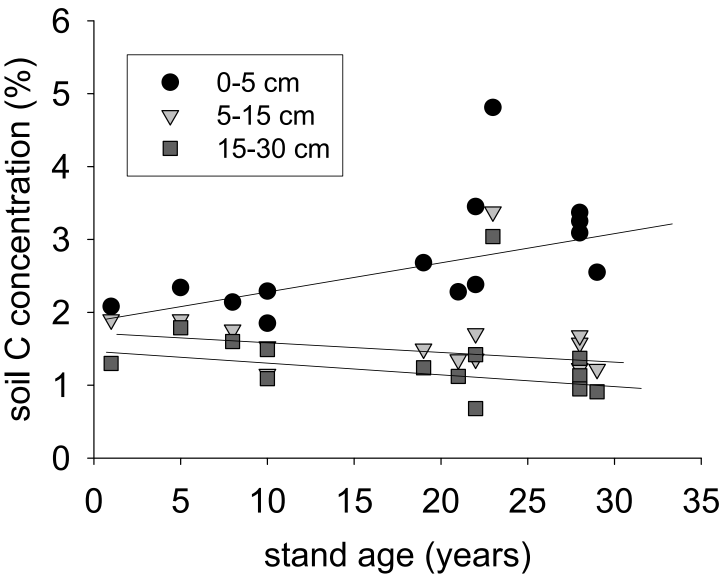

Figure 2: Carbon concentration in the mineral soil at three different depths of all forest stands. There was no significant difference between tree species.

Concentration and storage of N in mineral soil were not correlated with stand age, not affected by tree species, and not significantly different between pasture and forest stands. The average N storage in the Ap-horizon of the forest stands was 5.5 Mg N ha^{-1}(Figure 3b). Other studies reported no change or a decrease in N storage in mineral soil after afforestation (e.g. Hamburg 1984; Jug et al. 1999). A decrease in N with time could have been expected, assuming that soil N from former agricultural use is incorporated in the new biomass and input of mineral N through fertilization had ceased.

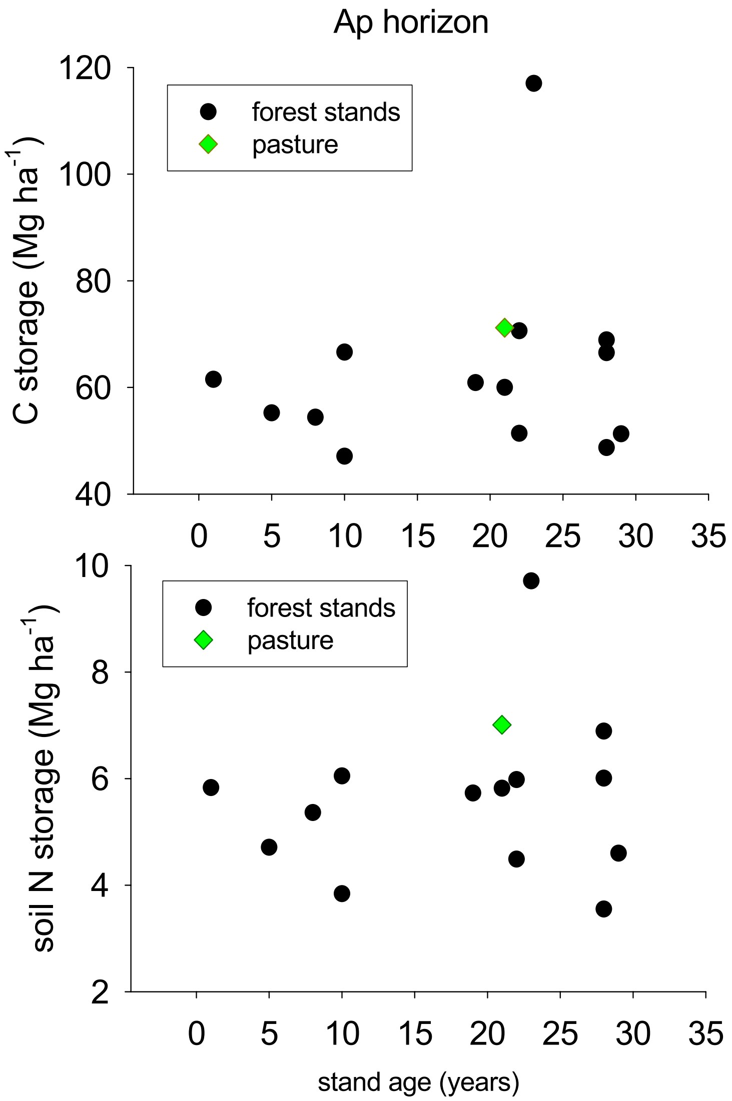

Figure 3. (a) Total C and (b) total N content in the Ap-horizon (0–25 cm depth) of all forest stands and the permanent pasture. There was no significant different between tree species.

The C/N ratio of the mineral soil ranged between 9.6 and 18.8 in all forest stands. Highest values (>10) were measured in 0–5 cm depth. This is in accordance with the general observation that C/N ratios decrease with soil depth (Post and Mann 1990). In the total Ap-horizon, neither an effect of tree species nor of time was found. The former intensive arable use of the soils may have affected the C/N ratio of the mineral soil. After 30 years, C/N ratios were still in the order of magnitude of cultivated soils. Similar effects of land-use history were reported by Compton et al. (1998).

Conclusion

It can be concluded that afforestation of arable soils results in changes of soil properties, but that changes were not significant in all soil layers and for all parameters investigated after 30 years. The most significant changes occurred in the forest floor and in the upper 0–5 cm of the mineral soil. Increase in C and N storage in the forest floor was mainly attributed to accumulation of litter material and therefore different between tree species. In contrast, C/N ratios and storage of C and N in the mineral soil of afforestation stands may probably not be influenced by the selection of tree species, at least within a time scale of a few decades. Results did not support the hypothesis that afforestation of former arable soils leads to increased C or N storage in the soil after already 30 years.

Hence, afforestation slowly changes soil properties derived from cultivation. Site history seems to be more important than the choice of tree species. After 30 years following afforestation, tree species differed only with respect to forest floor accumulation.

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2.21 Loss of nitrate after gap formation: Studies in Danish beech (*Fagus sylvatica* L.) forests of different management intensities

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Abstract

In the ongoing discussion about sustainable forestry, gap regeneration has been suggested as an alternative forest management practice with the aim of reducing losses of nitrate (NO_3^-) with seepage water. In the studies presented on the poster, changes in NO_3-N concentrations in soil solution below the rooting zone (90 cm depth) were followed for 2–3 years after gap formation. Losses of NO_3-N were estimated using the water balance model WATBAL. The study was carried out in a semi-natural and two managed beech *(Fagus sylvatica* L.) forests in Denmark. Gap diameters ranged from 18 to 30 m.

Soil solution NO_3-N concentrations and losses were increased in all gaps as compared to under the canopy. Nitrate-N concentrations were highest in the semi-natural forest, but this was not attributed to the gap formation as concentrations were high, both in the gap and under closed canopy. Nitrate losses from the gaps started to decrease along with gap closure above and below ground. No significant effect of gap size was found within the range of the investigated gap diameters and canopy heights.

Keywords: Forest ecosystems, gap, nitrate, soil solution, *Fagus sylvatica* L., WATBAL

Introduction

In recent decades, Danish research on forest ecosystems was motivated by an increasing interest in sustainable and nature-based forest management. Nature-based management seeks to maintain the biological and geochemical integrity of forest ecosystems along with a continuous timber production by applying natural forest dynamics (Attiwill, 1994). Gap formation, a typical small-scale disturbance in natural forest ecosystems, is therefore considered as a possible approach. However, practical experience with gap formation is scarce in Denmark. The objectives of the studies summarized on the poster were to investigate the effect of gap formation in beech (*Fagus sylvatica* L.) forests of varying structure and management intensity on concentrations and losses of nitrate-nitrogen (NO_3-N) in soil solution below the rooting zone (90 cm). Management intensities ranged from a semi-natural forest to conventionally managed forest stands. The effect of gap size was examined by creating four gaps of two different sizes in the managed forest stands. The results presented in this paper are a summary of the data published in Ritter and Vesterdal (2005) and Ritter et al. (2005).

Material and methods

The study was carried out in gaps of beech forests located on Zealand, Denmark, on nutrient-rich soil. The semi-natural forest reserve (Suserup Forest) is a heterogeneous forest with a high regeneration potential. The forest has never been intensively managed and has been protected for more then 100 years. It has nowadays regained the typical mosaic structure of natural forests of the temperate region. The gap investigated (~18 m diameter) was established naturally during a storm in December 1999. Average canopy height is 31 m. The two managed forest stands (Ravnsholte Forest and Hejede Overdrev) are homogeneous in structure and age class (75 years and 80 years, average canopy height 27 m and 28 m, respectively) and had no or only little regeneration and ground vegetation. Two gaps (~20m and ~30m diameter) were created in each stand by felling 3–12 trees in January 2001.

Measurements were carried along a north-south and a west-east (except for in Hejede Overdrev) transect running from the gap centre into the surrounding stands. Measurement periods were up to three years after gap formation, and samples were taken at approx. monthly intervals. Soil solution was sampled from below the rooting zone (at 90 cm depth) using teflon suction cups. Leaching losses of NO_3-N were estimated by the water balance model WATBAL (Starr 1999). For further details see also Ritter and Vesterdal (2005) and Ritter et al. (2005).

Results and discussion

Nitrate in soil solution

At all three sites, NO_3-N concentrations were generally higher in the area of the gaps than under the closed canopy. However, in the semi-natural forest differences between gap and closed canopy were only significant during growing seasons. Concentrations were unexpectedly higher in the semi-natural than in the managed forests: the maximum seasonal mean in the gap was 34 mg NO_3-N l^{-1}. No effect of gap size was seen in the two managed forest stands, and mean NO_3-N concentrations were 7.2 mg NO_3-N l^{-1} in the gaps compared to 2.2 mg NO_3-N l^{-1} under closed canopy. Overall NO_3-N levels were lowest in the gap where ground vegetation was almost absent (Hejede Overdrev, large gap). This was in contrast to numerous studies that have shown a decrease of elevated concentrations along with the development of a dense vegetation cover (Foster et al. 1989; von Wilpert and Mies 1995). Concentrations of NO_3-N in the semi-natural forest were also high compared to other Danish forest sites not managed for wood production. A study on NO_3-N concentrations below the rooting zone reported 0.7 mg NO_3-N l^{-1} for such forest sites (Callesen et al. 1999). Gap formation was not credited with the high NO_3-N levels because concentrations were generally high both in the gap and under closed canopy. These high concentrations occurred despite vigorously growing regeneration in the gap and no significantly increased N input by wet deposition or mineralization (Ritter and Bjørnlund 2005; Ritter et al. 2005). It is suggested that the status of this semi-natural forest as a long-term non-intervention forest reserve may have resulted in a high storage of N in living biomass and soil. Long rotation periods were shown to reduce the output of nutrients with export of biomass in managed forest stands (Hüttl and Schaaf 1995). This assumption is supported by a study in a traditionally managed forest in the vicinity of Suserup Forest. Receiving comparable amounts of N input by throughfall, NO_3-N concentrations below the rooting zone in that forest were still less than 1 mg l^{-1} (Beier et al. 2001). Thus, it seems that the internal N cycle of an ecosystem is important for the N balance after disturbances, as also reported in other studies (Gundersen et al. 2002).

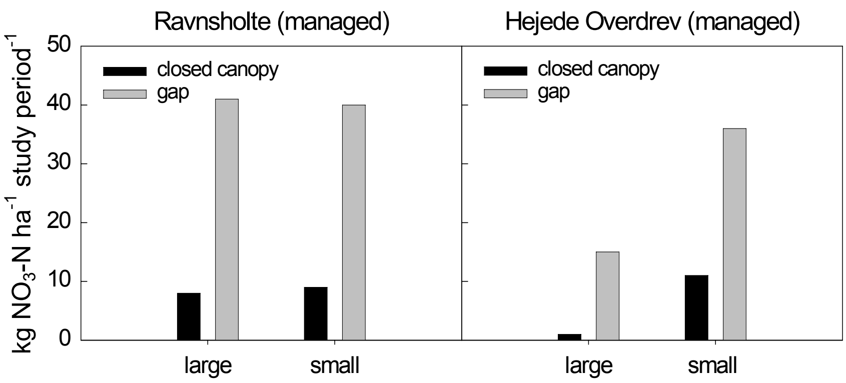

Figure 1. Leaching losses of nitrate-N at the four gap sites in the two managed forest stands: Nitrate losses are illustrated as the sum of the total model period of 20 months (September 2001 to June 2003)

Leaching of nitrate

Leaching loss of NO_3-N was increased in all gaps. This was attributed to both increased soil solution NO_3-N concentrations and increased soil water fluxes in the gaps. Leaching losses of NO_3-N decreased with time after gap formation, and no leaching losses occurred under the canopy during growing seasons. In the managed forest stands, seasonal average NO_3-N losses from the gaps ranged from 1.1 to 2.2 kg NO_3-N ha^{-1} (Ritter et al. 2005). For the whole study period, losses of NO_3-N were 3- to 13-fold higher in the gaps than in the surrounding forests (Figure 1). In the semi-natural forest, leaching losses from the gap were much higher, with seasonal averages decreasing from a range of 57 to 37 kg NO_3-N ha^{-1} in the first two years after gap formation to 3.8 kg NO_3-N ha^{-1} in the third growing season after gap formation (Ritter and Vesterdal 2005). Total losses from the gap were about four times higher than under the closed canopy in the first two years after gap formation, but almost the same in the third year (January–October) (Figure 2). This reduction in leaching losses was attributed to the vigorously growing regeneration in the semi-natural forest. Other studies have shown that leaching of NO_3^- decreases again as soon as available N is utilised by developing understorey vegetation and microbial activity (Barg and Edmonds 1999).

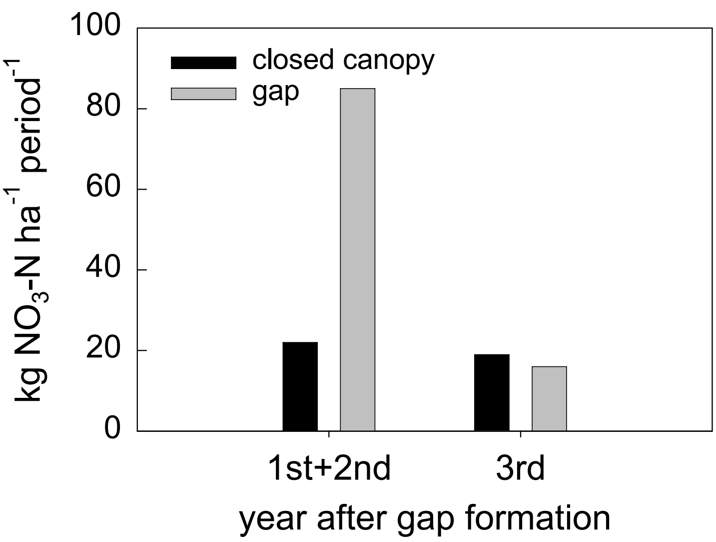

Figure 2. Leaching losses of nitrate-N in the semi-natural forest Suerup. Nitrate losses are illustrated as the sum of the first two calendar years and the third year (until October only) after gap formation, respectively.

Although no effect of gap size was found on NO_3-N losses in the managed forest stands in the first years after gap formation, it can be assumed that the small gaps are closed earlier than the large ones (Valverde and Silverton 1997) and that NO_3-N losses thus stop earlier as well. This would be a positive aspect which should be considered in the application of gap formation to nature-near forest management. However, further monitoring is required to determine if NO_3-N leaching declines earlier in smaller gaps and in the presence of ground vegetation. Results indicated furthermore that both above and below ground closure of the gap by roots, regeneration and mature trees bordering the gap contribute to gap closure.

Conclusion

Gap formation resulted in increased NO_3-N concentrations in the soil solution below the rooting zone in all gaps investigated. Gap size had no impact on the level of NO_3-N concentrations in gaps, but may be important when a more rapid closure of the gap contributes to decreasing NO_3-N concentrations. Factors which are generally considered to enhance high NO_3-N levels could not always explain the observations of the present study. High concentrations of NO_3-N occurred despite no significant N input by wet deposition, no increased mineralization, and a vigorously growing regeneration; low NO_3-N concentrations were found even though ground vegetation was almost absent in gaps. Presumably, the combination of all these factors had an impact on NO_3-N concentrations anyway. A positive impact of gap formation on ground water quality may be seen in the fact that increased losses of NO_3^- were restricted to small areas within a forest stand.

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2.22 Afforestation with oak: Effects of pre-commercial thinning on the development of ground flora

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Abstract

During the 1990s the oak area in Denmark increased by 13,000 ha to 43,000 ha. Most of the new oak stands originate from afforestation of former farm land. This paper reports a case-study of the development of ground flora in such stands following a wide range of different pre-commercial thinning practices. We conclude that the post-treatment change in species diversity is closely related to thinning grade. Apart from initial conditions such as seed sources, soil and other site factors, the result is very sensitive to the time at which field work is carried out, relative to the time of leafing foliation of the oaks.

Introduction

In Denmark, oak is an important commercial tree species with a high potential for economic revenue to the land owner (Skovsgaard 2004a). Moreover, oak forests host a large range of animals, plants and fungi (Rune 2001) and offer good opportunities for recreational activities. Based on these characteristics, oak provides a solid basis for sustainable forest management (Skovsgaard 2004b).

During the 1990s the oak area in Denmark increased by 13,000 ha to 43,000 ha (Larsen & Johannsen 2002). Most of the new oak stands originate from afforestation of former farm land. Stands are established by sowing or planting at spacings relevant for wood production. Due to the light demands of oak, it is usually considered necessary to carry out a series of (expensive) pre-commercial thinnings, typically three or four, to ensure satisfactory development of crop trees.

The management model for young stands is based mainly on results from a pre-commercial thinning experiment in the early 1900s (Hauch 1908, 1915). Results indicated that in young stands, thinning among dominant trees to remove undesirable individuals combined with heavy thinning among socially intermediate trees while retaining an understorey of suppressed oak trees is beneficial for the growth as well as the wood quality of potential crop trees.

In Denmark, this regime is widely practiced for the production of commercial, high quality oak timber on good moraine sites and is used as an inspiration also for oak under less optimal site conditions. Hence, pre-commercial thinnings are generally carried out mainly to promote the long-term economic potential of the stand, whereas other management objectives are given little consideration. This appears to be somewhat in contrast to contemporary guidelines for sustainable forest management.

During 2002–03 three statistically designed field experiments were installed in young oak stands at different locations in Denmark to investigate effects of alternative pre-commercial thinning practices on a range of tree and stand characteristics. The research objectives include wood production, wood quality, tree and stand health, ground flora, soil fauna and recreational opportunities. This paper reports the development of ground flora in one of these experiments.

Materials and methods

Experiment no. 1516, which was used for this case-study, is located in the Haslev Orned forest at Bregentved Estate, approximately 60 km south of Copenhagen (Skovsgaard 2006). The stand comprises even-aged pedunculate oak (*Quercus robur* L.) with a sparse admixture of hornbeam (*Carpinus betulus* L.).

The stand was established in spring 1989 by sowing on a former meadow, using 90–95 kg of acorns per ha. Seeds were collected locally in stands (seed sources F.661 and F.630) of Dutch origin. The area was fenced for approximately 10 years.

Experiment no. 1516 was installed in spring 2002 at age 13 years. At installation, the stem number before thinning ranged at 6,500 to 7,000 live trees per ha and stand height at approximately 5.5 m. The experiment includes eight treatments with different combinations of pre-commercial thinning grade and time of first pre-commercial thinning. All treatments have been replicated twice within the experiment in a block-design.

This study reports three-year effects on ground flora development in four different treatments in block 1 of experiment no. 1516 following the first pre-commercial thinning. Treatments included the unthinned control plot and plots thinned to a residual stem number of 1000, 300 or 100 crop trees per ha.

Ground flora development is being investigated at six permanently monumented sampling points in each experimental plot. The sampling points are located in the middle of the plot to avoid edge effects. Each point is marked with a blue, 70 cm long, ½" galvanized iron pipe.

The ground flora was recorded in a precisely located square of 1.00 m^2 at each sampling point. For each square metre the plant species present in all corners of a 10 cm^2 grid were recorded by the use of point intercepts. When more than one species was present only the uppermost was recorded to give a total figure of 1,000 records for each square metre.

The field work was carried out in the second week of May 2002 and 2005, exactly one week before leafing foliation. To indicate the large effect of seasonality on the cover of different plant species a meticulous photo documentation of the test plots was carried out both at the time of field work and 24 days later.

Due to the limited scope of this investigation, no statistical analyses were carried out.

Results

The ground flora cover for all four regimes are summarized in Table 1 for 2002 (the time of the first pre-commercial thinning) and 2005. All figures are the mean of six squares of 1.00 m^2. The species are arranged with monocotyledons, dicotyledons, and ferns in separate groups.

Table 1. Percent (%) cover of forest floor vegetation in three pre-commercial thinning regimes and in unthinned control plots at the time of the first thinning (2002) and three years later (2005).

	Unthinned 6870 trees/ha		Pre-commercial thinning 1000 trees/ha		Pre-commercial thinning 300 trees/ha		Pre-commercial thinning 100 trees/ha	
	2002	2005	2002	2005	2002	2005	2002	2005
MONOCOTYLEDONS:								
Poa trivialis	<0.1	0.1	0.3	19.7	11.2	20.2	<0.1	13.0
Poaceae sp.	<0.1	-	-	-	-	-	-	2.1
Deschampsia caespitosa	+	+	+	1.8	2.3	11.5	0.2	<0.1
Poa nemoralis	+	-	-	-	-	-	-	-
Epipactis helleborine	+	-	-	-	-	-	-	-
Brachypodium sylvaticum	+	-	-	-	-	-	-	-
Carex sylvatica	-	+	+	-	-	-	-	-
Milium effusum	-	-	-	0.1	-	-	-	-
Alopecurus pratensis	-	-	-	<0.1	-	-	-	<0.1
Juncus effusus	-	-	-	+	-	-	-	-
Carex remota	-	-	-	-	+	-	-	-
Dactylis glomerata	-	-	-	-	+	-	-	-
Juncus conglomeratus	-	-	-	-	-	0.3	-	0.3
Molinia coerulea	-	-	-	-	-	-	-	<0.1
DICOTYLEDONS:								
Urtica dioica	24.4	25.8	0.1	38.5	2.3	11.3	3.6	19.9
Rumex sanguineus	1.7	5.7	0.3	0.1	10.6	8.1	1.2	22.6
Veronica serpyllifolia	0.2	+	+	-	-	+	-	-
Ajuga reptans	0.2	0.2	+	1.7	-	-	-	-
Geum rivale	0.1	-	-	-	-	-	-	-
Epilobium adnatum	<0.1	-	0.1	+	<0.1	-	-	0.2
Crataegus monogyna	<0.1	-	<0.1	-	+	0.1	-	-
Caryophyllaceae sp.	<0.1	-	-	-	-	-	-	-
Rubus idaeus	<0.1	-	-	2.7	0.3	4.5	-	+
Glechoma hederacea	-	0.1	-	<0.1	-	-	-	-
Ranunculus repens	-	+	-	1.6	<0.1	8.2	0.5	16.0
Galium aparine	-	+	<0.1	0.8	-	0.3	0.2	<0.1
Cirsium palustre	-	-	<0.1	0.4	-	0.2	-	-
Geum urbanum	-	-	<0.1	0.3	-	+	<0.1	-
Taraxacum vulgare	-	-	<0.1	-	0.2	-	0.9	0.1
Atriplex sp.	-	-	<0.1	-	<0.1	-	-	-
Asteraceae sp.	-	-	<0.1	-	-	-	-	-
Calystegia sepium	-	-	<0.1	-	-	-	-	-
Chamerion angustifolium	-	-	+	0.3	-	-	-	-

Continued

	Unthinned 6870 trees/ha		Pre-commercial thinning 1000 trees/ha		Pre-commercial thinning 300 trees/ha		Pre-commercial thinning 100 trees/ha	
	2002	2005	2002	2005	2002	2005	2002	2005
Prunus padus	-	-	+	-	-	-	-	-
Epilobum montanum	-	-	+	-	-	+	-	-
Plantago major	-	-	+	-	-	-	-	-
Galeopsis sp.	-	-	-	0.3	-	-	-	-
Lonicera periclymenum	-	-	-	0.1	-	-	-	-
Rumex sp.	-	-	-	-	1.6	-	-	2.0
Caryophyllaceae sp.	-	-	-	-	-	<0.1	-	-
Capsella bursa-pastoris	-	-	-	-	+	-	-	-
Geranium dissectum	-	-	-	-	-	+	-	-
Scrophularia nodosa	-	-	-	-	-	+	-	-
Veronica sp.	-	-	-	-	-	-	0.2	<0.1
Cirsium arvense	-	-	-	-	-	-	-	10.4
Humulus lupulus	-	-	-	-	-	-	-	1.3
Mentha arvensis	-	-	-	-	-	-	-	+
Cirsium vulgare	-	-	-	-	-	-	-	+
Carduus crispus	-	-	-	-	-	-	-	+
FERNS:								
Filices sp.	-	-	+	-	-	-	-	-
Dryopteris sp.	-	-	-	0.5	-	<0.1	-	-

[- not present in the plot + present immediately outside the plot]

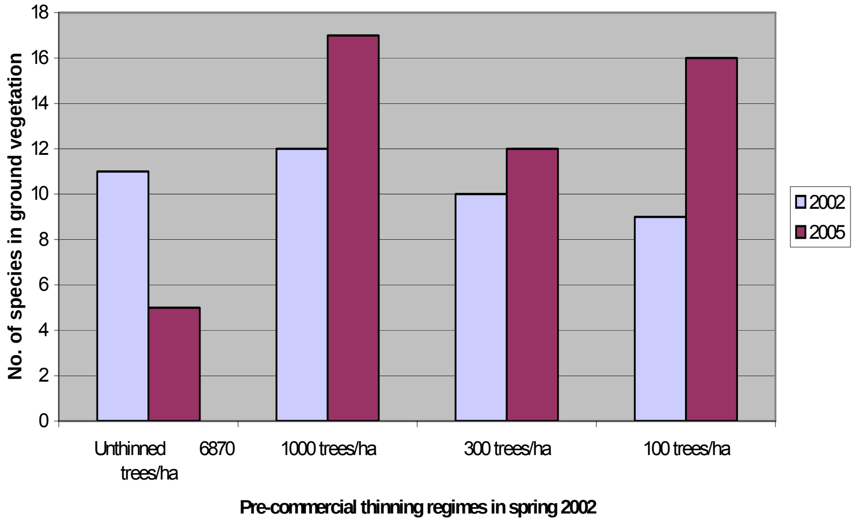

Figure 1. Development in species diversity of the ground vegetation (vascular plants) during the first three years after pre-commercial thinning.

The pre-treatment species diversity varied somewhat between experimental plots (Figure 1). Taking this into consideration, the three-year change in species diversity correlated positively with thinning grade (Table 2). While the species diversity of the unthinned control plot was significantly reduced (from 11 to 6 species) as the unthinned stand grew older, the species diversity increased for all of the actively thinned plots after thinning. The tendency was towards higher increases in species diversity with decreasing post-treatment stem number.

Table 2. Three-year change in species diversity in relation to initial, pre-treatment diversity.

	Un-thinned	1000 trees/ha	300 trees/ha	100 trees/ha
Initial species diversity	11	12	10	9
Three-year change in species diversity	−55 %	42 %	20 %	78 %

Going into further detail with the development of flora, there was a large exchange of species in the forest floor. Some species with a very low cover disappeared from 2002 to 2005, while a large number of new species were established in the plots during the same years (Table 1). A total number of 51 species were recorded in the 4 x 6 squares of 1.00 m^2. Only three species had a cover of more than 8 % of the area in any thinning regime in 2002 (*Urtica dioica* in the unthinned control, and *Poa trivialis* and *Rumex sanguineus* in the plot subjected to pre-commercial thinning to 300 trees/ha).

Three years after thinning *Urtica dioica* and *Poa trivialis* had a cover of more than 8 % of the area in all thinning regimes. *Rumex sanguineus* and *Ranunculus repens* had a cover of more than 8 % of the area in the two most heavily thinned plots, and *Deschampsia caespitosa* and *Cirsium arvense* had a cover of more than 8 % of the area in one of the two most heavily thinned plots.

Discussion and conclusion

The development of ground flora after thinning in this experiment has been quite as expected. The increased amount of light reaching the ground caused an increase in both diversity and cover of the florest floor vegetation, while the gradually reduced amount of light in the unthinned controls caused a decrease in both diversity and cover.

Most species that developed a cover of more than 8 % during the first three years after thinning were present in the area at the beginning of the experiment, but many other species with only a few plants present disappeared during the period. The large number of species being present in the area for just a very short period (probably a single season) indicates that there has been a large species pool present from which to recruit the fittest species at any time. Nevertheless, there was only one example of a species introduced to the area during the period which reached a cover of more than 8 % *(Cirsium arvense).*

Temporal variation in leafing foliation as well as the day in the season (which is not the same as the day in the year) seem to be very important for the cover of the different ground flora species (Figs. 2–9). Consequently, it is important always to carry out the field work on exactly the same day in the season. This day may be difficult to identify prior to leafing foliation.

Figures 2–9. Ground flora in pre-commercial thinning regimes of experiment no. 1516 photographed 13 May and 6 June 2005. The upper pair of photos shows the unthinned control, the second pair from the top is the 1000 trees/ha regime, the second pair from the bottom is the 300 trees/ha regime, and the bottom pair is the 300 trees/ha regime. Note, the extreme difference in ground vegetation cover from left to right developed in less than four weeks (photos: F. Rune)

Though the thinning experiment is still at a very early stage it is clear that thinning practice has a marked influence on the ground flora, even when not using shade-tolerant tree species such as spruce or beech for afforestation. In youth, the diversity of herbal species in an oak forest floor may decrease rapidly in an unthinned stand, while it may more than double in a few years if a heavy pre-commercial thinning is practiced (again, depending on the flora seed sources).

The long-term effects of thinning practice in oak stands on the ground flora are still quite uncertain, but we would not be surprised if heavy pre-commercial thinnings at an early stand-age would introduce and enable a large number of light-demanding herbal species to survive for a considerable part, or possible all of the rotation period.

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2.23 Total area of planted forests in Iceland and their carbon stocks and fluxes

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Abstract

Iceland has lost about 95% of its birch woodlands during the 1,100 years of human settlement, resulting in the lowest forest cover of Europe. Presently, birch woodlands are covering ca. 1.2% and afforestation areas cover ca. 0.3% of the total area (28,900 ha). Until now, no national map has existed on planted forests in Iceland and the area of annual afforestation has been estimated from the number of seedlings planted annually. Here we show for the first time a national map of planted forests and give the first results from the National Forest Inventory of Iceland.

Using the information we now have about changes in the annual afforested area we could estimate the total annual carbon sequestration based on a long-term average carbon sequestration potential of 1.2 t C ha^{-1} year^{-1}. This showed that afforestation areas planted since 1990 in Iceland had sequestered 64,000 t CO_2 in the year 2000. This was ca. 3% of Iceland's CO_2 emission in 1990. Afforestation is therefore seen to play an important role in Iceland climate policy in the future.

Finally, data from ongoing research projects on carbon sequestration potential in young planted forests are detailed.

Keywords: Kyoto-forests, precommercial thinning, fertilization, Iceland

Introduction

In 1990, the woodland and forest area in Iceland was estimated to be 129,000 ha (1.290 km^2) or approximately 1.2% of the total land area (Snorrason et al. 2005). The first forest plantation was established in Iceland in 1899. In 1990 planted or seeded stands of native birch and various imported species were estimated to cover 7,600 ha (Snorrason et al. 2005). In 2003, 82% of forest plantations in Iceland were established using five tree species, Siberian larch, mountain birch, Sitka spruce, lodgepole pine and black cottonwood (Figure 1). The planting has dramatically increased in the 15 years since 1990, from ca 1 million seedlings planted annually to ca. 6 million seedlings.

In 1999, the Icelandic government decided to increase the forested area of Icelandic lowlands (below 400 m a.s.l.) to at least 5% within 40 years (Stjórnarrád Íslands, 1999). This would about double the forested area of Iceland, if all birch woodlands are also included as forests. To reach this target, an afforestation rate of roughly 17 million trees yr^{-1} is needed in comparison to 2003's five million. The annual planting has been increasing in recent years. It is, however, highly uncertain if afforestation will increase to the necessary 15–18 million trees yr^{-1} in the next few years to fulfil the goal of the Icelandic law.

Until now, the total afforestation area in Iceland was estimated from data on the number of seedlings planted annually, with certain assumptions about stand density and initial mortality (e.g. Sigurdsson & Snorrason, 2000). The statistics on annual planting have been found to be fairly accurate and are published annually in the Journal of Icelandic Forestry (Skógræktarritið). In 2005, a new sample-based National Forest Inventory (NFI) was launched by Icelandic Forest Research. The Icelandic forest inventory is organized similar to the NFIs in the neighbouring countries, e.g. Sweden, Norway, Finland and Denmark.

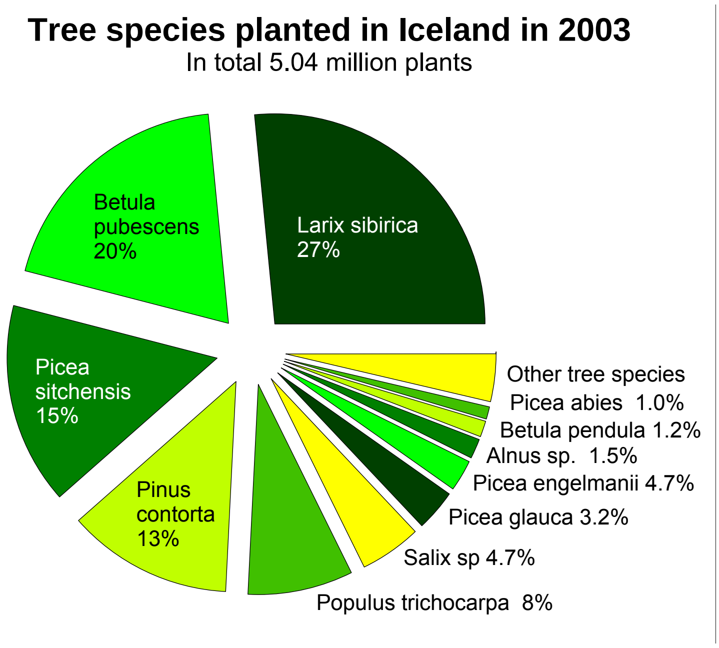

Figure 1. Tree species planted in Iceland in 2003. Data from Gunnarsson (2004).

The main goal of this paper was to present the first national map of afforestation areas in Iceland and show the first real statistics from the NFI. The second goal was to make a prediction on national carbon sequestration of afforestation areas initiated since 1990.

Methods

The National Forest Inventory will be complete in five years (2009). It is based on systematic sample plots, laid out in a 500 m vs. 1000 m sample grid in all mapped afforestation areas > 0.5 ha. These include mostly plantations, but in some cases they are seeded areas. The total number of plots that will be measured during the five years is 700. The present results on forest areas are based on the first year sample, 126 plots.

Mean annual C sequestration rate of 1.2 t C ha^{-1} yr^{-1} were used to estimate C stock changes in all forest plantations in Iceland. This mean C sequestration potential includes average changes in aboveground biomass and coarse roots and is based on the number of published studies of C sequestration potentials of afforestation areas in Iceland (e.g., Sigurdardottir, 2000; Sigurdsson and Snorrason, 2000; Snorrason et al., 2002). This estimate is valid for forest plantations up to 50 years of age, and has been applied for all tree species. It gives a conservative estimate of C sequestration, since average values for a number of 35–50 year old forest plantations have yielded as much as five times as high sequestration potentials (e.g. Snorrason et al., 2002; Sigurdardóttir, 2000).

Results and discussion

According to NFI the total afforestation area of Iceland was 28,900 ha in 2005 (Figure 2; Table 1). Because of the increase in planting in the 1990s, most of this area, or 74%, has forest stands younger than 15 years (Table 1). Because of the limited number of sample plots, the area estimate involves a relatively large uncertainty. The accuracy of the estimate will be improved as more plots are sampled by the NFI during the next four years.

It was not until 2003 that the assumptions used for estimating total annual plantation area from seedling numbers could be validated against real mapping of afforestation areas from the same year (Snorrason & Kjartansson, 2004). The first results from the NFI are surprisingly close to older estimates, which were not based on actual mapping. According to the NFI the area of afforestation areas older than 15 years (pre-1990) was 6,300 ±1,115 ha (Table 1). This can be compared to an older estimate of 6,600 ha made by Sigurdsson and Snorrason (2000).

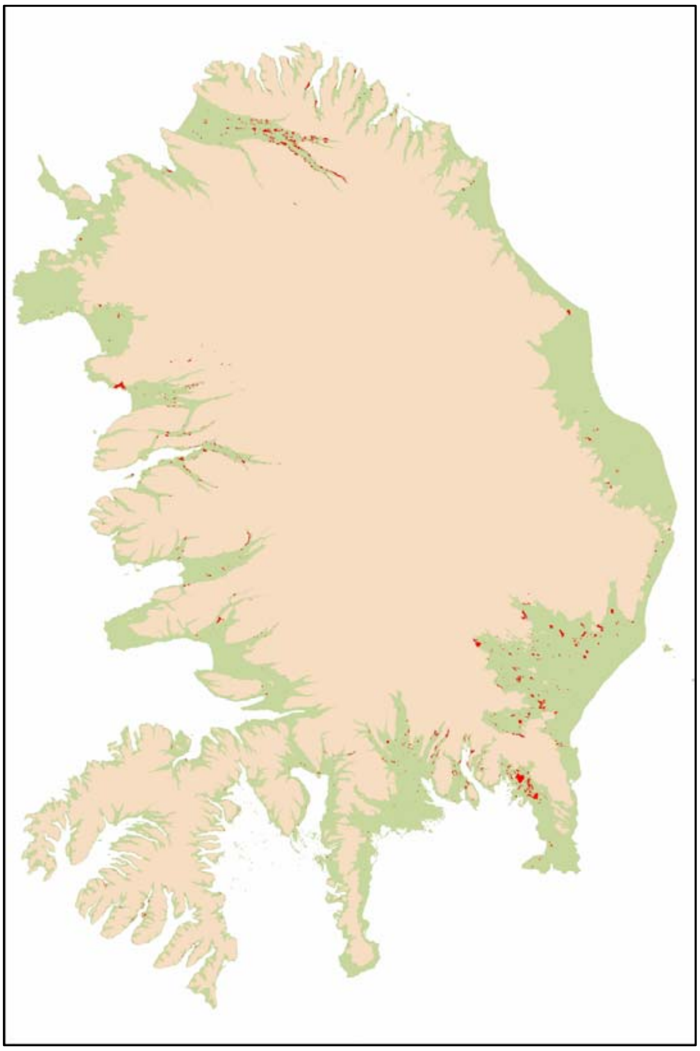

Figure 2. National map of afforestation areas in Iceland (red). The light green area shows land below 200 m a.s.l. Tree limit in Iceland is approximately at 400 m a.s.l.

Table 1. Age distribution of planted forests in Iceland according to the first year results from the NFI. Reforestation refers to when native mountain birch woodlands have been converted to managed forests, usually by planting coniferous seedlings.

	Estimated area		Number of plots	Standard error	95% Confidence interval
Afforestation	*ha*	*%*		*ha*	*ha*
Since 1990	21,500	74%	86	1.178	2.357
Before 1990	6,300	22%	25	1.115	2.229
Reforestation	900	3%	4	469	938
Undefined	200	1%	1	224	448
Total	28,900				

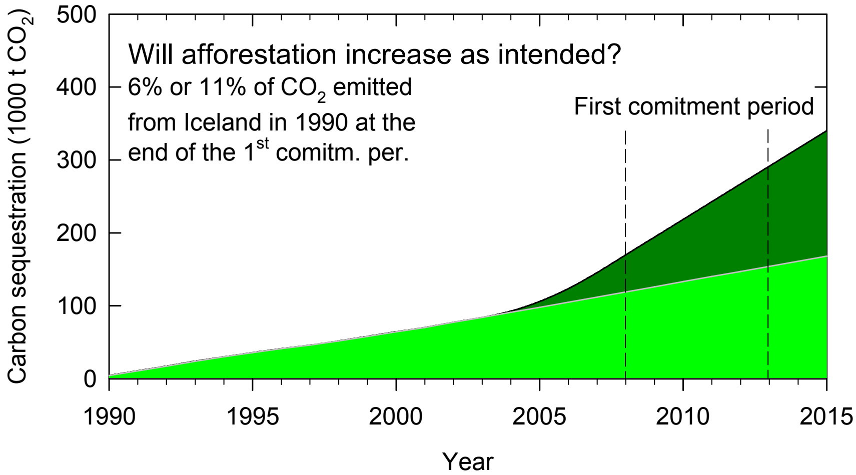

Figure 3. Carbon sequestration by afforestation in Kyoto forests in Iceland during 1990 to 2015 estimated by a single C sequestration potential of 1.2 t C ha^{-1} yr^{-1}. After 2003 two scenarios have been used; business as usual with ca. 5 million plants planted per year (light area) or a gradual increase in forest planting according to the current laws about Regional Afforestation Programs in Iceland that have the goal of tripling the annual plantings (dark area).

In Figure 3 we show a coarse estimate of carbon sequestration during 1990–2015 using two scenarios; 5 million plants planted per year and a gradual increase to 17 million plants planted annually after 2008. We used 1.2 t C ha^{-1} yr^{-1} as a mean C sequestration rate across all species and site conditions in Iceland. Since the mean average age, weighed by area, of the forest plantations was only 20 years, no large-scale harvesting had started yet in planted forests (Sigurdsson & Snorrason 2000). Removals have therefore been practically zero. The 1.2 t C ha^{-1} yr^{-1} constant includes mean aboveground biomass increment of plantations that have been thinned once (Sigurdsson & Snorrason 2000). According to the estimate in Figure 3, where a single sequestration potential was used, afforestation areas planted since 1990 in Iceland had sequestered 64.000 t CO_2 in the year 2000. This was ca. 3% of Iceland's CO_2 emission in 1990 (Ministry for the Environment 2003). If planting continues with ca. 5 million plants per annum to 2015, the annual C sequestration of afforestation areas will have increased to ca. 6% of the 1990 CO_2 emissions in 2013, but could be as much as 11% if planting increases to 17 million plants per annum.

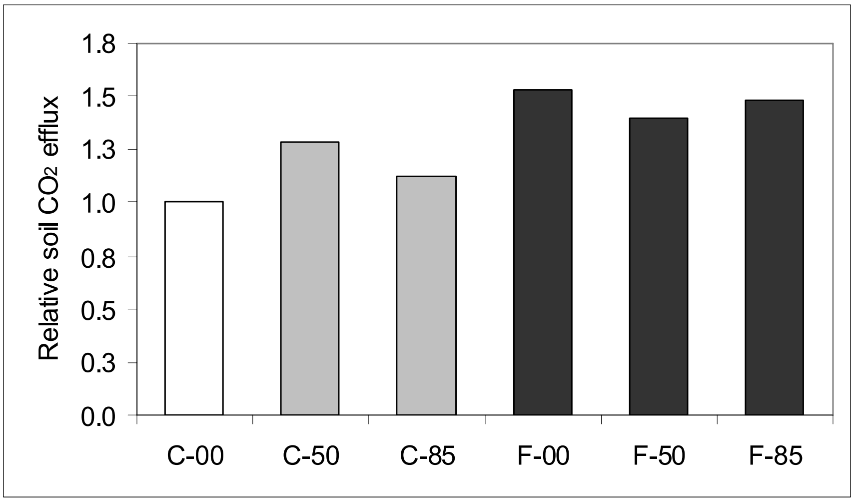

Figure 4. Relative changes in soil CO_2 efflux from a 15 year old Populus trichocarpa stand with stand density of 10,000 trees ha^{-1} (C-00) one year after 50% precommercial thinning to 5000 (C-50) and after 85% thinning to 2000 (T2) trees ha^{-1}, respectively. The same thinning treatments are repeated with 80 kg N fertilisation (F).

Currently, there are two research projects running in Iceland where carbon sequestration potentials of afforestation areas are being studied in more detail. The first is the Ph.D. work of Brynhildur Bjarnadottir at Lund University. Brynhildur is comparing three different ways to estimate ecosystem carbon sequestration for afforestation areas in Iceland: stock-change approach (harvesting), ecophysiological modelling and micrometeorological measurements by eddy covariance. This project is described in detail in another article in this issue (Bjarnadottir and Sigurdsson 2007).

Another research project is trying to determine the 'short-term' effects of forest management practices (thinning and fertilisation) on carbon cycling and productivity of a young black cottonwood plantation that was established in 1990. This research will help to determine the effect of those management practices on aboveground carbon sequestration, as well as to monitor whether the treatments affect the soil carbon pool by making repeated measurements of soil carbon efflux (Figure 4).

Even if the forest management of young stands had not increased the soil CO_2 efflux significantly ($P = 0.76$) in the above example (Figure 4), there are clear trends for more carbon storage in aboveground biomass in the same treatments (Figure 5). Both precommercial thinning and fertilisation significantly increased the relative diameter increment (thinning $P < 0.001$; fertilisation $P<0.001$), while there was no significant interaction between those treatments ($P = 0.08$). The relative height increment was significantly increased by the fertilisation ($P < 0.001$), whereas thinning did not have significant effects ($P = 0.25$). There was, however, significant interaction between thinning and fertilisation on the height increment ($P = 0.007$).

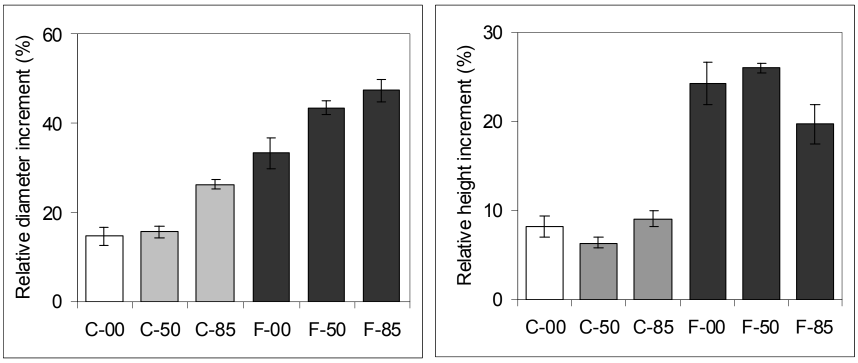

Figure 5. Relative changes in relative diameter increment (left panel) and relative height increment (right panel) in a 15 year old Populus trichocarpa stand with stand density of 10,000 trees ha^{-1} (C-00) in the second year after 50% precommercial thinning to 5000 (C-50) and after 85% thinning to 2000 (C-85) trees ha^{-1}, respectively. The same thinning treatments were repeated with 80 kg N fertilisation (F-00, 50, 85).

These results seem to indicate that precommercial thinning and forest fertilisation have more effect on aboveground carbon storage than on soil carbon efflux. The data from this project need, however, to be analysed further before the net effect can be fully stated.

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2.24 Energy production and carbon balance of a young tree plantation

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Abstract

The biomass production of four tree species (birch, maple, poplar and willow) under a short-rotation plantation system is discussed. The 4-year old plantation studied here was established on former agricultural land in March and April 2001. Poplar and willow showed the highest mean actual biomass production (3.5 and 3.4 t DM ha^{-1} y^{-1} resp.). Regarding the energy stored in the biomass produced, values ranged from 25.8 MWh ha^{-1} for maple to 78.8 MWh ha^{-1} for poplar after four years of tree growth. The potential electricity production from short-rotation forestry (SRF) biomass in Flanders is expected to be only 1 % of the total electricity consumption. The CO_2 emission reduction potential of SRF plantations is very limited too, mainly due to the low biomass production and land scarcity in this region. The overall carbon balance (carbon uptake by the trees – carbon released from the soil) was negative for most plots, even after the 4th growing season. However, the poplar plots already had a tendency to become a sink for carbon.

Keywords: Biomass production, calorific value, carbon balance, CO_2 emission reduction, energy, short-rotation forestry, soil respiration.

Introduction

Since 1970, the interest in the establishment of short-rotation forestry (SRF) plantations strongly increased in Europe. The biomass produced of these plantations can be used as a substitute for fossil fuels, preventing as such the emission of greenhouse gases into the atmosphere. These plantations are also mentioned in the Art. 3.3 and Art. 3.4 of the Kyoto Protocol (KP) as a possible measure to sequester carbon. As such, the establishment of SRF plantations could help countries to fulfil their commitments to the KP. Belgium, as one of the EU countries, committed itself to a 7.5 % reduction of greenhouse gas emissions during the first commitment period of this KP. In this study, the biomass production after a rotation period of four years in a SRF plantation with four species is analysed. An indication is given of the energy production and the CO_2 emission reduction potential of SRF plantations in Flanders (Belgium). Finally, the carbon balance of the plantation is calculated. From this balance, it can be concluded whether this young ecosystem acts as a sink or source for carbon.

Material and methods

Short-rotation plantation

In March and April 2001, a short-rotation plantation was established on former agricultural land by hand-planting. The site is situated at Zwijnaarde (51°02' N, 3°43' E), which is located 10 km south of the centre of Ghent (Belgium). The site is characterised by a temperate maritime climate, with moderate temperature variation, prevailing westerly winds, a heavy cloud cover and regular rain fall (mean: 780 mm). At the start of the experiment, the sandy soil of the plantation had a homogeneous upper layer of 30 cm depth, with a mean organic carbon concentration of 1.0 % and a pH_{KCl} of 4.5. The total area of the plantation is 8800 m^2, and is composed of 22 plots of 400 m^2 each. Poplar (*Populus trichocarpa x deltoides* – Hoogvorst), willow (*Salix viminalis* – Orm), birch (*Betula pendula* Roth) and maple (*Acer pseudoplatanus* L. – Tintigny) were planted on eight, seven, four and three plots respectively. Twenty cm cuttings of poplar and willow were planted with an initial density of 20000 stems ha^{-1}, while birch and maple were planted as two-year-old saplings, with a density of 6667 stems ha^{-1}. No weed control, fertilisation or irrigation was performed in the plantation.

Biomass production

In January 2005, the diameter at 30 cm height (d_{30}) of 20 randomly chosen trees per plot was measured with a mechanical calliper. Site- and species-specific allometric relationships of the form $AGDM = a.d_{30}^{\,b}$ were used to convert d_{30} (in mm) into the total aboveground biomass (*AGDM*, in g DM) of the tree (Tahvanainen & Rytkönen 1999, Nordh & Verwijst 2004).

Multiplying the mean *AGDM* per tree by the initial tree density gave the potential aboveground biomass. For poplar and willow, which were planted as cuttings, this aboveground biomass was equal to the potential biomass production after 4 growing seasons. As birch and maple were planted as young trees, the planted biomass (3.0 g $tree^{-1}$ for birch, 5.1 g $tree^{-1}$ for maple) was subtracted from the aboveground biomass to calculate the potential biomass production. The actual biomass production was calculated based on the mean *AGDM* per tree and the actual tree density. This actual density was determined in the field in January 2005, by counting all surviving trees per plot.

Energy content of the wood

The calorific value of wood indicates its energy content. This calorific value (kJ g^{-1} DM) was determined for the four species with an oxygen bomb calorimeter. Combining information of aboveground biomass (t DM ha^{-1}) and the calorific value of the wood gave the amount of energy stored in the biomass. It can be supposed that in Flanders, a maximum of 10,000 ha will become available for short-rotation forestry in the future. When co-burning is chosen to produce electricity from biomass grown on these plantations, the conversion efficiency (*CE*) is approximately 37 %. As the mean electricity need of one household is known to be 3300 kWh_e y^{-1}, the total number of households that can be provided with electricity from these 10,000 ha SRF plantations can be calculated.

CO_2 emission reduction potential

Burning of biomass from SRF plantations is considered as a CO_2 neutral process [IEA Bioenergy, 2002]. As such, the carbon emission reduction resulting from the substitution of fossil fuels by SRF electrical energy was calculated by multiplying the maximum amount of electrical energy that could be produced by 10,000 ha of SRF plantations in Flanders with the amount of CO_2 released during 'traditional' electricity production processes. The oldest coal plant in Belgium emits 263.9 kg CO_2 per GJ electricity produced, while the emission was estimated at 136.1 kg CO_2 GJ_e^{-1} for the most modern gas turbine. Besides co-burning, with a conversion efficiency of 37 %, two other conversion processes were considered: burning of biomass (conversion efficiency of 16 %) and gasification (*CE* of 27 %).

Carbon balance

In this study, the carbon balance is considered as the net amount of carbon taken up by the trees minus the carbon released from the soil as soil respiration. The carbon balance was studied on six plots of the plantation in Zwijnaarde, and on two control plots, which were not planted with trees.

To determine the carbon uptake, monthly measurements of Leaf Area Index and Specific Leaf Area (m^2 g^{-1}) were performed. Every month, the d_{30} (mm) of 20 trees per plot was measured and transformed in aboveground biomass by the allometric relations mentioned above. As the root-to-shoot ratio was also determined in Zwijnaarde, the amount of belowground biomass was calculated based on the *AGDM* of the tree. Fifty percent of the DM was supposed to be carbon. The difference in the total above- and belowground carbon stock in the biomass between the 1st January and the 31st December was considered as the annual carbon uptake by the trees.

Soil respiration (g CO_2 m^{-2} h^{-1}) was measured fortnightly with an automatic closed chamber system (EGM-1, PP-systems) on 3 rings in every plot. Simultaneously, soil temperature (°C) was measured at a depth of 5 cm next to the PVC soil respiration ring (diameter 18.8 cm). Integration of these measurements over time gave the total soil respiration during a specific period.

Results and discussion

Biomass production

As can be seen from Table 1, poplar had the highest potential and actual biomass production at the plantation in Zwijnaarde, while maple clearly had the lowest production. The survival rates for maple and willow were very high, while for birch and poplar, many more trees died during the four years of the experiment (Table 1). The heterogeneity of soil characteristics as pH, C and N content, C/N ratio and bulk density up to 1 m depth did not explain the large range in biomass production of one species within this plantation. Compared to other European studies, biomass production in Zwijnaarde is rather low. However, the pH (4.5) and the soil type (sandy soil) at our plantation are only suboptimal for the growth of poplar and willow. In other studies, weed control, fertilization or irrigation was applied, which was not the case in Zwijnaarde. Moreover, the plots in Zwijnaarde were 400 m^2 each, while in most other studies plots of less than 200 m^2 were used. It is suggested in the literature that the production on smaller plots gives an overestimation of production levels on larger scaled plots.

Table 1. Mean survival rate (%) and mean potential and actual biomass production (t DM ha^{-1} y^{-1}) of birch, maple, poplar and willow after four years of tree growth; different letters indicate significant differences (p=0.05).

Species	Mean survival rate	Potential biomass production (t DM ha^{-1} y^{-1})		Actual biomass production (t DM ha^{-1} y^{-1})	
	(%)	Mean (s.d.)	Range	Mean (s.d.)	Range
Birch	75.8	3.3 (0.7)^b	2.7–4.4	2.6(0.7)^{a,b}	2.1–3.7
Maple	96.8	1.2 (0.5)^a	0.7–1.7	1.2 (0.5)^a	0.6–1.7
Poplar	86.3	4.2 (0.9)^b	2.8–5.4	3.5 (0.7)^b	2.6–5.0
Willow	97.6	3.5 (1.5)^b	1.4–5.9	3.4 (1.5)^b	1.4–5.8

Energy production from biomass

The mean calorific value was lowest for maple (19.4 kJ g^{-1} DM), intermediate for poplar (19.6 kJ g^{-1} DM) and willow (19.9 kJ g^{-1} DM), and highest for birch (21.3 kJ g^{-1} DM). These values were comparable to calorific values of different bio-energy crops mentioned in literature, which ranged from 13.5 to 24.0 kJ g^{-1} DM. The total amount of energy stored in the biomass was 25.8 MWh ha^{-1} after 4 years of tree growth for maple (Table 2), and was 74.8, 77.4 and 78.8 MWh ha^{-1} for willow, birch and poplar respectively. This means that although birch trees were planted at a lower density (6667 trees ha^{-1}) than willow (20,000 trees ha^{-1}), and although the mean biomass production of birch was lower than that for willow (Table 1), the total amount of energy stored in the biomass was slightly higher for birch than for willow. This was due to the high calorific value of the birch wood. As can be seen from Table 2, the maximum number of households that could be provided by electrical energy was 22,095 per year. This is only 1% of the total number of 2.2 million of households living in Flanders. This implies that the possible contribution of electricity from SRF biomass to the overall electricity consumption in Flanders is very limited.

Table 2. Energy stored in the biomass after 4 years of tree growth and number of households that can be provided by electricity produced from this biomass.

Species	Biomass energy	Households
	(MWh ha^{-1})	(# y^{-1})
Birch	77.4	21723
Maple	25.8	7234
Poplar	78.8	22095
Willow	74.8	20966

CO_2 emission reduction potential

In Figure 1, the CO_2 emission reduction potential of 10,000 ha of SRF plantations of birch, maple, poplar and willow are presented. Emission reductions were highest when bio-energy production systems were compared to the oldest Belgian coal plant. Depending on the conversion process chosen (co-burning, burning or gasification), using electricity produced by biomass instead of fossil-fuel based electricity can reduce CO_2 emissions with 9.8 to 69.3 kt CO_2 y^{-1} (Figure 1a). Reductions compared to a modern gas turbine ranged from 5.1 to 35.8 kt CO_2 y^{-1} (Figure 1b). Results were of course strongly dependent on the amount of energy stored in the biomass, which resulted from the combination of both the potential biomass production and the calorific value of the wood of a specific tree species. The total CO_2 emission in Flanders in the year 2000 amounted to 76264 kt CO_2. This means that the CO_2 reduction potential of SRF plantations in Flanders is only 0.09 % of the total CO_2 emissions.

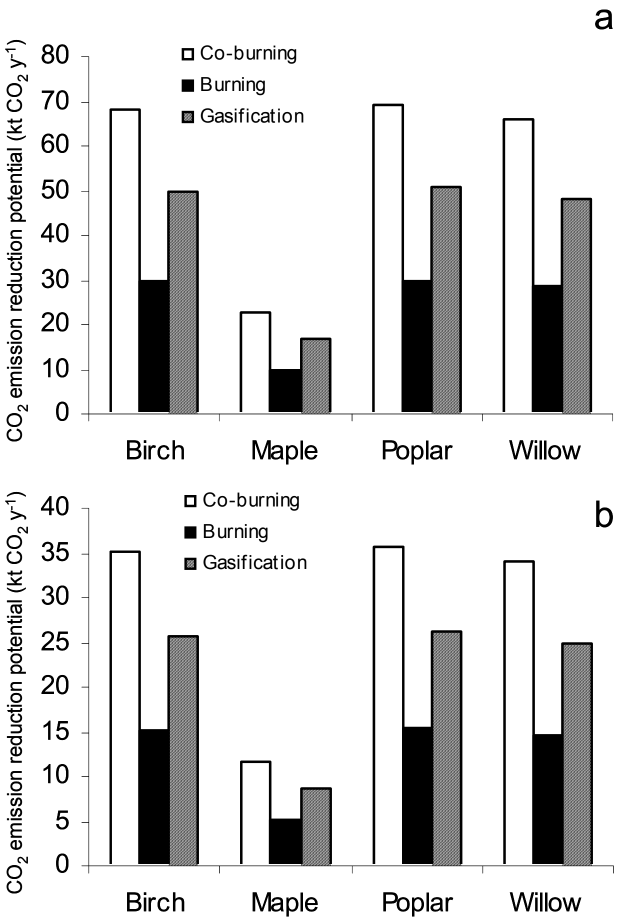

Figure 1. CO_2 emission reduction potential (kt CO_2 y^{-1}) of 10000 ha of birch, maple, poplar and willow SRF plantations compared to (a) the oldest coal plant of Belgium and (b) the most modern gas turbine.

From these results, it can be concluded that the use of biomass grown under SRF will only be of minor significance from the point of view of reaching the Kyoto Protocol targets for Flanders. The critical parameters for this are the low biomass production levels found on our plantation, and the land scarcity in Flanders, which inhibits the extension of the area that will become available for SRF plantations. Moreover, farmers in Flanders request that legislation will be made more transparent, as at the moment, it is not clear if SRF plantations are considered as arable land or as forest. However, SRF plantations have other benefits as the improvement of soil physical properties and the prevention of soil erosion, or they can have a recreational function or serve as a (temporary) habitat for many species (e.g. breeding birds).

Carbon balance

In 2002, the amount of carbon taken up by the trees was lower than the total soil respiration for all plots (Figure 2a). However, compared to two plots which were not planted with trees, the overall carbon balance for the planted plots was less negative, which means that these plots were a smaller source for carbon than when the area is not planted with trees.

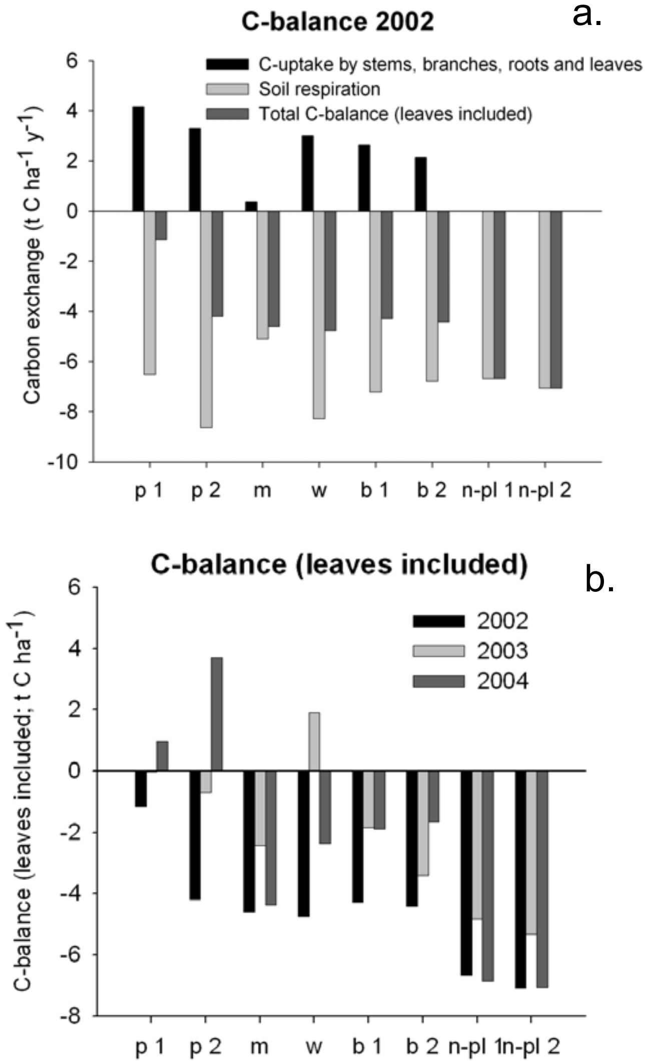

Figure 2. (a) C-uptake by the trees, soil respiration and C-balance for the year 2002; (b) C-balance for the years 2002, 2003 and 2004; p = poplar, m = maple, w = willow, b = birch, n-pl = non-planted (control) plots.

In 2003, the willow plot appeared to be a sink for carbon (Figure 2b), while the other plots were still losing C. In 2004, the carbon uptake in the two poplar plots was larger than the soil respiration. The maple and birch plots, and the non-planted plots, were still a source of C after 4 years of tree growth. For these plots, the balance was more negative in 2004 than in 2003.

The amount of carbon taken up by the trees was increasing from year to year (Figure 3a), and therefore did not explain the more negative C-balance in 2004 compared to 2003. The soil respiration on the other hand was lower in 2003 than in 2002 and 2004 (Figure 3b). This lower value found in 2003 was mainly caused by lower temperatures that year, in combination with a dry summer period.

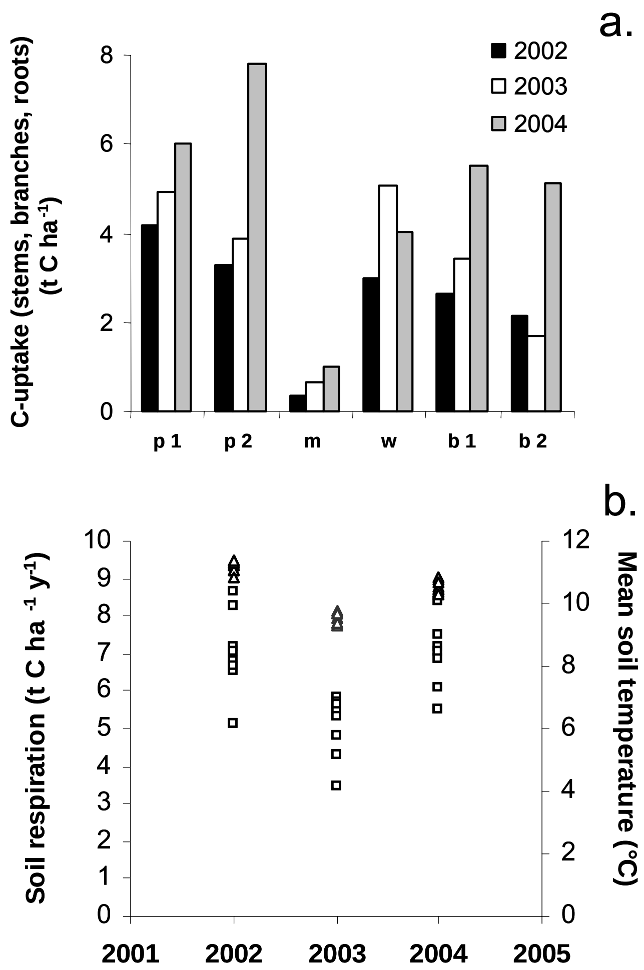

Figure 3. (a) C-uptake by the trees in 2002, 2003 and 2004; (b) soil respiration (squares) and soil temperature (triangles) in 2002, 2003 and 2004; p = poplar, m = maple, w = willow, b = birch

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3. Landscape

3.1 Identifying and assessing landscape through historic landscape characterisation

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Abstract

Landscape is as much a product of physical as well as mental transformations. Change and creation are an inevitable part of the human adaptation and utilization of landscapes. Managing this change so that it is sustainable without loss to landscape character is a challenge we all face. The landscape can be seen both in terms of its physical features, the archaeology, as well as the intangible perceptions that have been attributed to it by people in the past. These remnants allow archaeologists to create research tools and to create dialogues between different professions to help manage change in the landscape. This paper will demonstrate historic landscape characterisation (hlc) as a tool for research and in managing landscape change. As a result the identification and assessment of the forces for change, such as afforestation, will be made and assessed in light of historic landscape character.

Introduction

Today's visible and understood landscape is the product and culmination of many different processes, both natural and cultural, that have occurred in the past. The landscape as it is perceived by each of us is defined in different ways. This is mainly a perception of difference based on our own experiences, but it is also a conceptual judgement as we each imagine our immediate environment as a representation of how it actually is; our landscape. In this paper I will introduce one example of landscape representation that is mapped from the existing landscape, but in terms of the past influences that have helped shape it. In doing so I am introducing an example of applied archaeology which has grounding for useful applications in land use management, sustainability and biodiversity; this includes afforestation projects as well as other agents of landscape change. In mapping the landscape I will be introducing historic landscape characterisation (hlc) as a method that gives historic context to landscape change, creation and continuity.

Landscape as cultural heritage

The idea of landscape as a concern of cultural heritage is not new; in Iceland it exists in the current antiquity legislation (Thjódminjalög 2001, Sect. IV, Minjasvaedi, fornleifar og forngripir, Art 9). Acknowledging landscape as a cultural heritage concern, however, suggests a need for its conservation, perhaps either through protection or its management. The 'active' protection of landscape is beginning to be replaced by 'passive' management in several European countries (ESF COST A27 meeting in Denmark May 2005). The former involves the selective designation of landscape areas, in which a detailed understanding and management of a bounded landscape area, its threats and condition are placed under supervision without the threat of change or destruction; essentially fossilising areas based on specific criteria for protection. Passive management on the other hand acknowledges the comprehensiveness of a landscape, whether ordinary or spectacular. In doing so pressures on the landscape, big or small, can be assessed reflexively to a wide number of issues; the notion that landscape is dynamic and continually evolving, as suggested in the introduction to this paper, is one that should remain in force. Historic landscape characterisation (hlc) therefore is a tool used for the management of cultural landscapes to gain a broadbrush comprehensive understanding of the historic and cultural landscape that can be used to assess the impacts on landscape, amongst other concerns.

In order to provide a framework on which to hang ideas about landscape and create cross-departmental and cross-disciplinary dialogues, which are so essential in managing landscape, it is useful to consider the European Landscape Convention's (ELC) general definition of landscape (Council of Europe 2000; Fairclough & Rippon 2002, 227–232).

"Landscape means an area, as perceived by people, whose character is the result of action and interaction of natural and/or human factors." (European Landscape Convention: Council of Europe 2000, Article 1a)

Within the ELC definition archaeologists are given scope to develop several specific themes. Firstly, landscape is defined as an area rather than individual places, a distinction that is important as it allows archaeologists to consider the collective influences that a number of sites have had on the landscape rather the usual single one, such as through excavation and field survey. It also acknowledges that landscape is comprehensive and exists everywhere, in both natural and cultural states, though in many respects, as is the case in Iceland, it is a biocultural product: even seemingly natural states in the lowland areas of Iceland have been heavily influenced by cultural activity. Secondly, the idea of change is embedded in the words 'action and interaction'. This is a primary concern for archaeologists as we study change daily and we are best placed to consider and contribute to discussions about the change to landscape, with special reference to how the landscape has developed in the past to the present day; understanding past change gives great weight to understanding a landscape in a contemporary context: glancing back when looking to the future (pers. Com. Simon Bell Affornord conference, Reykholt 2005). Thirdly, landscape by its very definition is a cultural entity 'as perceived by people' and therefore can not be viewed simplistically in terms of either culture or nature. Landscape, unlike environment, is interpreted and subjective, rather than defined as fact (hence the difficulties in defining it succinctly).

Past and present-day landscape

Change, continuity and creation are recurring themes in this paper. Archaeologists celebrate and welcome change in particular. For example, archaeologists find the phasing of different buildings or the removal of archaeological deposits and identifying changes in colour or texture in the soil, as of paramount interest and great research potential. The landscape, also in this respect, seen as an arena of complex change, allows archaeologists to create a deeper understanding of past cultures and societies, observing the ways in which adaptation to the landscape has occurred through time. Today, landscape change is an inevitable fact; it is part of its dynamic, and the past was no exception. However, change in the more distant past was not as contentious, bar a few examples, as it is today.

Cultural activities, human 'action and interaction', have transformed landscapes in the past and continue to be the key agents in landscape change. Evidence for past grazing pressures, wood clearances, utilization and construction, can be seen everywhere in today's landscape. However, the communities of the past were not composed of reckless subsistence farmers; rather they invested time and energy in creating land management practices, such as the sub-division of lower lying upland pasture areas by boundaries, or defining specific land-use areas within their farm land (Aldred *et al*. 2004; Thomson 2003). Another key agent of change in the past was the natural environment. Trends in climatic variation suggest that physical changes to landscapes have varied across time. Greenland ice core data show a steady decline in climatic conditions until around 1425, with another key change in 1700. This has led to the modelling of climatic variation to illustrate birch and grassland coverage with small fluctuations in temperature (McGovern et al., forthcoming, fig 5). When viewed in connection with cultural activities the pace of change has increased rapidly. Considering the dichotomy of culture and nature is vitally important when attempting to understand changes in the landscape; one can not be understood without the other, particularly in Iceland.

The forces for change in today's landscapes are rapidly altering and creating new landscapes. There are several impacts on the historic landscape that are quickening the rates of change: agricultural expansion, buildings and road construction, mining, forestry plantations and natural impacts such as erosion. However, cultural changes dominate the causes of change. One of the fundamental questions that need to be asked is what are acceptable degrees of loss or change for modern society? With almost any kind of development or impact on the landscape, there are a number of factors that ought to be considered in the decision making, for example, visibility and aesthetics, the identity of place and the loss of non-renewable heritage resources. Cultural heritage through the application of hlc has a key role to play in helping shape and manage landscape change.

Characterisation

With special reference therefore to the ELC definition of landscape, hlc is a useful tool in helping to manage positive present-day landscape change. Historic landscape is defined as any collection of elements that have been formed in the past and that have shaped or influenced the development of the landscape. The source of information is primarily derived from archaeological material and an understanding of past environments. These elements or features can either be part of the living landscape, i.e. continue to function within the present day, or as relict features, i.e. no longer functioning within the present-day landscape but contributing to features of the present-day landscape.

Characterisation is a well established method in several countries in aiding the management of landscapes (Countryside Agency and Scottish Natural Heritage 2002; Fairclough & Rippon 2002, 169–182). Importantly, it divides the process of characterisation from decision making, and in this way is accountable and transparent as well as reflexive and applicable to different landscape factors and priorities. Characterisation is area based even though the information it uses may be based on point data; this creates a common language through landscape for the communication of specialised archaeological information. Characterisation uses a comprehensive approach, in that all parts of the landscape are characterised according to set criteria, regardless of their intrinsic values. Embedded in the hlc approach is the concept of time-depth which shows how the past has contributed towards the character of present-day landscape. One useful application of hlc is the creation of baseline data that are area based and comprehensive and which are used to measure, monitor and assess the impact of developments and changes to the (historic) landscape. This is important for cultural heritage and its role in the planning process, particularly in Iceland. Total survey coverage of all archaeological sites is many years away, but forms part of the requirements that are needed for Environmental Impact Assessments and municipal planning.

The hlc method is GIS based and uses classifications of landscape types or character types as attributes on which to base the analysis. It is fundamentally a subjective process and interpretative (by archaeologists with specialist skills) but uses actual data derived from cartographic and archaeological sources, allowing objectivity and transparency to be built into the characterisation process. The concept and method of hlc has been carried out in several European countries: England, Scotland, and Denmark for example. (Aldred & Fairclough 2003; Dyson-Bruce *et al*. 1999; Møller 2004). The approach uses a series of nested character types, allowing it to be used for different scales of work. In Iceland the method requires a dual approach in characterising the landscape, using both its material or physical features as well as how people in the past and today perceived and continue to perceive it. The perception of landscape is difficult to characterise but it has an inherent time-depth quality. Through time the attitudes and meanings of landscape have varied; for example, parts of the upland areas in Iceland were used for sheep grazing, either under controlled or open conditions, but today are unused or developed for industry. Perceptions such as these can be mapped through place names, in the identification of activity areas, such as grazing, and by mapping natural sites, such as stones, that have been given meaning by referencing them to specific events, either real or mythical. In this way points and perceptions are transformed into area-based character mapping.

Results and discussion

Regional difference in historic character is one research outcome produced by using hlc. In the following case studies each landscape area has been characterised according to the same criteria and in the same way. In Grimsnes, south Iceland, farm activities are clustered around the river Úlfljótsvatn, as well as in the east of the study area (figure 1.). In Adaldalur, north-east Iceland, farming activity is linear rather than clustered and is primarily associated with the valley bottom and immediate sides (figure 2.). Expansion and improvement of land into farmed land outside the homefield and beyond the valley bottoms occurs only in Adaldalur, suggesting a different farming requirement than in Grimsnes. Each of the other character categories can be analysed in a similar way. Correlation with the archaeological point data also demonstrates a clustering around the main farming areas, but subtler associations also exist in the upland areas where the character type may be strongly associated with movement activities and perceptive character types such as folklore or farming activities such as the gathering of sheep.

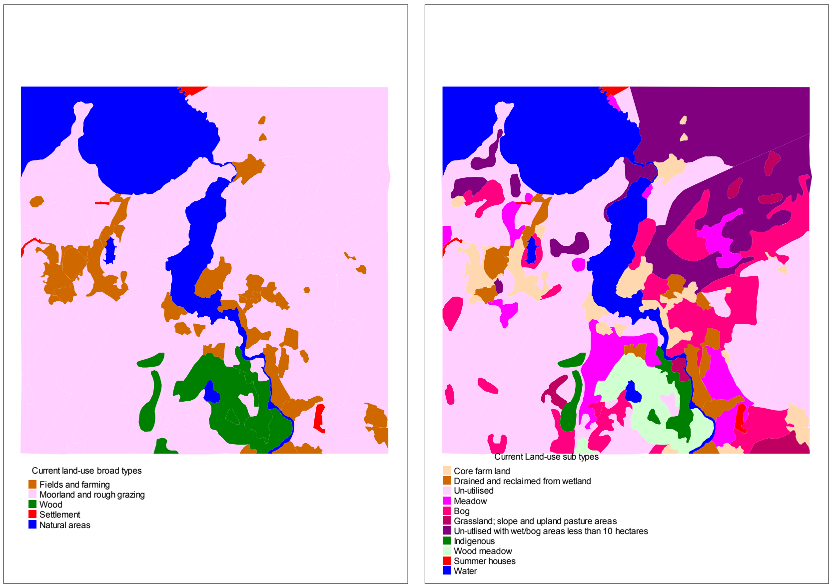

Figure 1. Grimsnes, south Iceland (Broad characterisation on left, detailed on right) [http://www.instarch.is/instarch/rannsoknir/annad/landscape/]

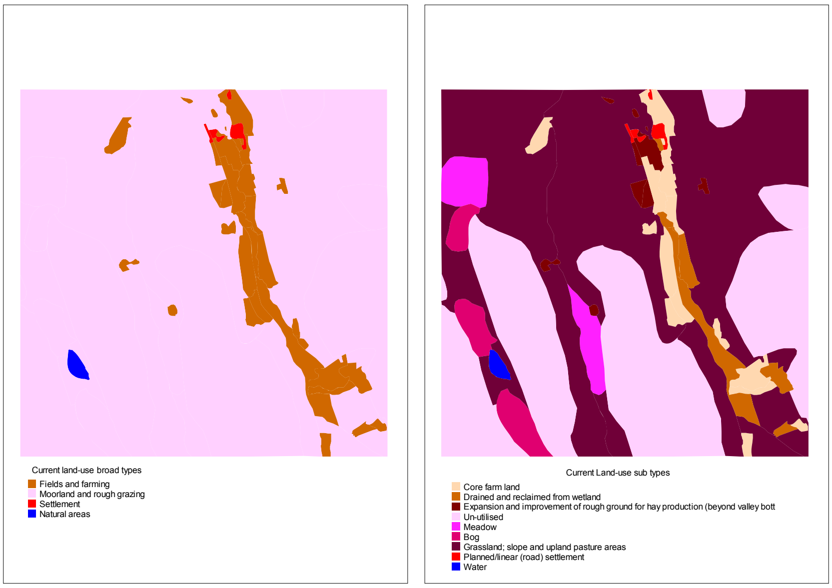

Figure 2. Adaldalur, nort east Iceland (Broad characterisation on left, detailed on right) [http://www.instarch.is/instarch/rannsoknir/annad/landscape/]

A number of applications can be developed from the hlc. As already suggested, the baseline data helps to manage change in the landscape, for example, ascertaining and predicting where and what the impact will be on cultural heritage from afforestation programs. Profiling the type of archaeology within each character type can then be used to create predictive or sensitivity maps to help guide change. The testing of research questions can also be analysed using hlc. For example, farm sites with high tax values may have a proximity to meadow or wet land which is good for cattle husbandry (Vésteinsson et al. 2002, 117–125). The creation of narratives about landscape areas that are based on perception areas rather than data points also allows the cultural landscape to be more effectively communicated and considered.

Iceland's landscape is very distinctive. It is open and has high levels of dispersed activity, with concentrations in some areas. It has great regional variety in its physical characteristics and this influences the cultural landscape, particularly the edge between it and the 'pristine' wilderness. Whilst large parts of the landscape seem to have been unaltered, cultural activities have shaped and changed them since the settlement of Iceland in the late 9th century, for example, land uses connected with grazing, deforestation and farm expansion for example. More recently, urban expansion and industry as well as afforestation are having an effect on the landscape. Accounting for the changes to landscape in the past allows perspectives on the future landscape to be made. Only by mapping the present-day landscape and its historic dimension, where the past meets the future, can landscape, as the sum of all its parts, be managed positively.

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3.2 Strange ideas: Subjectivity and reality in attitudes towards afforestation in Iceland

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Abstract

The goal of this study was to summarise attitudes towards afforestation as they have been publicly expressed in recent years in Iceland and classify them with respect to subjectivity/objectivity and reality. A search was carried out for articles published in newspapers where an attitude or opinion (positive or negative) was expressed concerning afforestation. Attitudes and opinions were assessed as to how subjective or objective they were by looking at the authors' own supporting evidence as well as evidence from other sources. Subjective attitudes were those based primarily on emotions and those rated objective were based on scientific or other well documented evidence. Attitudes were also classified as to how realistic they were based on the foreseeable level of afforestation in Iceland. Attitudes expressed varied greatly with respect to subjectivity and reality and most were not well supported by evidence.

Keywords: Afforestation, attitudes, reality, subjectivity

Introduction

The Law of Controversy: Passion is inversely proportional to the amount of real information available. (Benford 1980).

Since 1990, afforestation in Iceland has developed from being the harmless hobby of a few eccentrics to being a generally accepted, state-supported activity of a large and growing number of landowners. Iceland's forest area is small, and even though it is increasing more rapidly than before (Sigurdsson & Snorrason 2000), forests will continue to be a very minor part of the landscape for a long time to come. However, afforestation sites from the 1950s – '80s are becoming noticeable in the landscape, even though they do not cover large areas, making it possible for people to visualise the outcome of larger scale afforestation.

These developments have been met with a variety of attitudes from people, ranging from optimistic rejoicing to concerns about negative consequences. Among the most common venues for expressing opinions are letters and articles in newspapers. Taken together, they form a sort of national discourse on a variety of topics. Anyone who is willing to put their opinions in writing can participate and occasionally a debate ensues consisting of several letters over a period of time, often with many people participating.

In this paper, we investigate attitudes regarding afforestation in Iceland as expressed in letters and articles in newspapers and attempt to categorise them with respect to subjectivity and reality. The aim is to provide people working in forestry with an insight into public opinion regarding afforestation.

Materials and methods

The raw material for this study consisted of newspaper clippings as provided by a company that gathers such clippings by subject and republishes them (Fjölmidlavaktin 1984–2004). Clippings on forestry spanning the years 1984–2004 were gleaned for letters and articles expressing attitudes or opinions specifically on afforestation. The opinions expressed, along with supporting evidence, if found in the letters themselves, were recorded. The opinions were then paraphrased and grouped according to the point of view from which the effects of afforestation were being discussed. They were: 1) land use, 2) landscape, 3) effects on people, 4) the economy, 5) nature conservation and 6) exotic species.

Originally, the intent was to use supporting evidence in the articles themselves to rate the opinions according to a subjectivity index (NRRC 2002). However, most articles contained few references to supporting evidence, regardless of whether or not such evidence existed. The level of subjectivity was therefore rated according to the answer to a single question: Can the opinion be tested scientifically? If the answer was no, then the opinion was considered subjective, if yes, objective. Opinions were considered intermediately subjective/objective if they were indirectly testable or if testing them would be extremely complicated, difficult or unlikely to yield a clear result. No attempt was made to ascertain whether or not the opinion had in fact been validated scientifically.

Opinions expressed were also rated with respect to how realistic they were, using the scale of afforestation in Iceland as a basis, it being very limited with respect to land area (effects on land use, landscape and nature conservation) but larger with respect to population (effects on people and the economy). Opinions were classified as realistic, exaggerated or extreme.

The two authors rated both subjectivity and reality separately. Where their outcomes differed, a discussion resulted either in compromise or one convincing the other. No count was made of the number of letters expressing each opinion, since opinions expressed in letters to newspapers do not quantitatively reflect public opinion in general. This was a qualitative study.

Results

A total of 62 letters and articles were found where attitudes or opinions regarding afforestation were expressed. The opinions put forth can be summarised by viewpoint and paraphrased as follows:

Land use

1) Afforestation does not fit well with other land use.
2) Afforestation fits well with other land use.
3) Afforestation should be mostly/exclusively restricted to eroded land.

Landscape

4) Afforestation beautifies land.
5) Afforestation spoils the view.
6) Afforestation can be reversed.

Effects on people

7) Participation in afforestation activities is good for your physical and mental health.
8) Forests are important for outdoor recreation.
9) Afforestation impedes travel.

Economy

10) Afforestation builds a resource and provides jobs.
11) Afforestation will not result in an economically viable resource.
12) Tourists do not want to see forests in Iceland.

Nature conservation

13) Afforestation can be used to reach specific conservation goals.
14) Afforestation is a threat to various values (birds, plants, habitat, wetlands…).
15) Afforestation is or is not nature conservation.

Exotic species

16) Exotics do not fit into the Icelandic landscape.
17) Exotics are invasive, polluting, dangerous…
18) Only native species (and local seed sources) should be used.
19) Exotic species are useful.

Both positive and negative attitudes towards afforestation were expressed within each of the viewpoint categories. Exotic species were included as a viewpoint category because a large number of letters touched on this subject and it was obvious that many negative opinions toward afforestation actually stemmed from the use of exotic species.

Classification of the opinions with respect to subjectivity and reality resulted in 8 opinion groupings, ranging from opinions that were both objective (scientifically testable) and realistic (consistent with the scale of afforestation) to those that were both subjective and extreme. No opinions were grouped as both subjective and realistic (table 1).

Table 1. Summary of paraphrased opinions by viewpoint category and their subjectivity and reality ratings.

	Realistic	Exaggerated	Extreme
Objective	8) Good for outdoor recreation 19) Exotics are useful	6) Can be reversed 7) Good for health 9) Impedes travel 13) Conservation goals	17) Exotics are dangerous 18) Use only natives
Intermediate	2) Fits with other land use	1) Does not fit with other land use 10) Economic resource 11) Not economic resource 14) Threat to values	12) Tourists do not want to see forests
Subjective		3) Only afforest eroded land 4) Beautifies land 5) Spoils the view	15) Is/is not nature conservation 16) Exotics do not fit into landscape

Discussion

In reading the letters critically and searching for references to supporting evidence for the opinions expressed, it became clear that very few people felt it necessary to cite scientific results to support their opinions. Commonly, people justified their opinion with another opinion. For example: "*exotic conifers are undesirable*" (opinion 1) because "*conifers in straight rows do not fit into the Icelandic landscape*" (opinion 2). Others included references to what has been lost, i.e. the original birch woods. This was used both by supporters of afforestation ("*Iceland was wooded, therefore we should make it that way again*") and those against using exotic species ("*The original forests were birch woods, therefore we should only use birch*").

Emotionally loaded words and phrases were often used, commonly having something to do with nationalism or aesthetics. Choice of words often made the difference between an opinion being classified as extreme or merely exaggerated. However, an extreme position is often more easily testable than a less extreme one, resulting in it being classified as more objective. For example, the idea that afforestation could pose a threat to various values is related to the opinion that exotic tree species are dangerous, the difference essentially being that the latter is more extreme.

That afforestation threatens various values was classified as exaggerated, i.e. unlikely because of the small scale of afforestation, and intermediately subjective since testing whether such threats are likely to reach unacceptable levels is unlikely to yield clear results. The opinion that exotics are dangerous, that they for example "*spread like wildfire and exterminate natural vegetation*", is an extreme position but at the same time more objective, since it can be more easily defined and tested.

Opinions regarding whether or not afforestation fits well with other land use were put forth with respect to sheep farming, raising horses and most recently cultivation of arable land. The argument was that afforestation was or was not in competition for land with these other types of land use. Whilst it is true that it is difficult to cultivate a forest in the presence of sheep grazing and impossible to grow barley under a forest canopy, it is equally true that land use planning almost always entails parcelling land and separating different types of land use in time and/or space. Opinions may differ over how specific parcels of land should be used. However, considering the scale of afforestation, the opinion that afforestation will reduce appreciably the amount of land available for other land use in the foreseeable future is exaggerated.

The opinion that afforestation should be carried out on eroded land is subjective. Afforestation is carried out on both eroded and non-eroded land, but whether the emphasis should be on afforesting land with one cover type or another is a question of goals. This opinion was worded in two different degrees, exaggerated and extreme. The extreme degree excluded afforestation of non-eroded land. It could be expressed in a positive light: "*afforestation should concentrate on reclaiming eroded land and thus help to alleviate soil erosion*". However, it was more often expressed in a negative context to the effect that: "*vegetated land is, at least potentially, valuable for grazing, cultivation or conservation and afforestation should therefore be relegated to eroded land*". In other words, this was not the opinion of people who wanted to kill two birds with one stone, increasing forest and reclaiming eroded land at the same time, but rather of people generally against afforestation who could grudgingly accept afforestation of land that was worthless for other purposes.

That afforestation either beautifies land or spoils the view are purely subjective opinions, since they were not expressed in terms of whether or not afforestation actually changed the landscape or the view but whether that change was good or bad. Some writers exaggerated these effects, comparing Iceland to Finland for example, thus deviating quite far from reality.

The opinion that the effects of afforestation can be reversed was put forth by people defending afforestation as an answer to the concern about forests spoiling the view: "*if the forest spoils the view, it can be cut down, thus reclaiming the view*". This is an objective opinion in that it can be tested, but exaggerated. Forests can certainly be cut down, but there is considerable opposition to it. It is technically possible, but may be socially unrealistic.

All three opinions in the effects-on-people category are objective. That forests are important for outdoor recreation is also realistic as seen by the importance that people place on forests for recreation (Curl & Jóhannesdóttir 2005). Considering scale, it is unlikely that afforestation has much of a general health effect or that forests impede travel to any extent, so these opinions were classified as exaggerated.

Opinions as to whether or not afforestation will result in development of an economically viable forest resource are intermediately subjective. They are testable but not directly, since they both entail predictions of future conditions. In both cases, those who held these opinions cited either general or specific conditions abroad. Both of these opinions were classified as exaggerated. In this case, non-actual may be a better term to use than exaggerated, in that they deal with something that may or may not be important several decades in the future.

Whilst it is probably true that most tourists do not have forests in mind when deciding to visit Iceland, the wording of this opinion, i.e. that "*tourists do not want to see forests in Iceland*" renders it extreme. Less exaggerated wording, such as "*tourists do not come to Iceland in order to see forests*", would be more realistic.

The effect of afforestation on specific conservation goals, such as reducing soil erosion, improving water quality or sequestering carbon can be measured. This opinion is exaggerated in that the effect will be small compared for example to the scale of the soil erosion problem in Iceland, to say nothing of the negligible effect afforestation in Iceland could have on reducing global warming.

Taken together, all vegetation types (including eroded land and cultivated land), all landscape features (including cultural landscape), all archaeological sites (real or suspected) and historical places should be protected from afforestation in someone's opinion. Generally, this is a reaction against change, with the perception that afforestation is the most likely agent of change in the landscape. Many of the values putatively threatened by afforestation were either poorly defined, such as biodiversity, or very difficult to measure with respect to effects of afforestation, such as bird populations. The opinion is therefore classified as intermediately subjective. It is exaggerated, again because of the small scale of afforestation, even though afforestation certainly changes the environment where it is practiced.

Supporters of the opinion that afforestation serves conservation goals often stated that afforestation entailed nature conservation and those who emphasized threats to values often stated that afforestation was in opposition to nature conservation. Both positions are subjective and classified as extreme, since they are meant purely to elicit an emotional reaction from the reader.

The opinion that exotic tree species do not fit into the landscape is both subjective and extreme, because it is obviously exoticness itself and not the various effects of individual species that is in question. The position that only native species should be used is an expression of nationalism and even “localism” in the guise of conservation or even science, alluding to the idea that local races must be best adapted. It is at least intermediately objective since whether or not a local species or provenance is better adapted than an exotic one is testable. This opinion was often connected to reclamation of the original birch woods, which increased subjectivity. It is an extreme position in that exotic species and provenances are much used in afforestation and that this is not likely to stop. The opinion that exotics are useful for reaching a variety of goals is on the other hand both testable and realistic.

Opinions expressed were often more specific than the paraphrased ones presented here. For example, one of the dangers of afforestation with exotic species is that of forest fires. This is certainly an objective opinion since without forests there will be no forest fires. It is also a meaningless tautology; automobiles increase the danger of automobile accidents, birth virtually guarantees death.... Other strange ideas included the opinion that participation in afforestation would reduce “*drinking and devilry*” (a public health effect) and, conversely, that forests provide places for “*drinking and taking drugs*”, which could either be considered a negative social effect or classified as outdoor recreation, depending on your point of view.

There was no shortage of logical fallacies and fuzzy reasoning in the majority of letters and articles studied. However, one group of opinions stood out as being realistic and well supported by evidence. These opinions were that forests are important for outdoor recreation and that exotic tree species can be useful, both positive attitudes towards afforestation. Since no negative attitudes made it into this group, we were worried that perhaps a bias in favour of afforestation had crept into our classification. However, another look at the articles in question revealed that they were written in response to exaggerated or extreme attitudes against afforestation expressed in other letters or articles. They were written with the intent of being reasonable in the face of extreme views. Those expressing attitudes against afforestation could possibly have written in a similar vein, but none did.

Finally, attitudes expressed in newspapers, whether they are subjective or objective, realistic or extreme, majority opinions or those of a small minority, are opinions genuinely held by the people who take the time to express them in this way. They can influence the opinions of others and more importantly they can influence public policy. This is not a venue that can be ignored by the forestry sector. It not only gives an insight into what people are thinking, but also provides opportunities for correcting misunderstanding and countering attitudes based on faulty reasoning.

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3.3 Leisure landscapes: understanding the role of woodlands in the tourism sector

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Abstract

The Leisure Landscapes project employed qualitative research methods to explore the interface between forestry and tourism in Great Britain. In particular it aimed to investigate how tourism providers perceive current and potential values and uses of forests for tourism. It also explored their interactions with forest managers and feelings about the development of relations between forestry and tourism managers. In addition, the strengths and weaknesses of forest management practices for tourism were examined.

The research revealed the diverse and complex nature of relationships between forests and tourism providers and the potential benefits of closer integration between different products and services which constitute forest tourism. The desire for and the potential benefits of stronger partnership working between forest managers and tourism providers and the importance of forest managers more explicitly considering the availability and accountability of forest related resources and processes to tourism providers was identified. Ultimately, the potential value in taking a landscape scale approach to forest management for tourism is emphasised.

Keywords: Forestry, tourism, forest managers, tourism providers, values, uses, partnerships, landscape scale management.

Introduction

This paper presents some of the key findings from the Leisure Landscapes research project – an investigation into the current and potential role of forestry in the tourism sector in Great Britain.

Whilst forests in Great Britain have been used for leisure purposes since medieval times, their utilisation for tourism is a relatively contemporary phenomenon (for example see Rackham O., 1990 for a historical overview). Even so, throughout the 20^{th} century tourism and recreation were seen as relatively subsidiary uses in a large proportion of forests, many of which were primarily planted for timber production. However, with the advent of increased competition within the global timber market and the associated downward pressure on prices, as well as perceptions of increasing consumer demand to pursue leisure activities, recreation and tourism have moved from being a peripheral to central foci of sustainable forest management (Forestry Commission, 1998, 2001 and Scottish Executive, 2000).

These trends in forestry reflect change within society more broadly and in particular the movement from an industrial to post-industrial economy. As this transition takes place, the countryside is increasingly viewed as a space for consumption rather than production Marsden (1992). With this, comes the need to diversify the economic dependency of rural areas away from productive agricultural and forestry activities. Even in areas, such as Scotland, where there is a greater emphasis on timber production, tourism is seen as a means of forest managers diversifying sources of income and spreading risks. The promotion of forests for tourism has therefore been strongly grounded in arguments about the ability of forestry to promote economic development and in particular the diversification of the rural economy, through the creation of forest tourism products and services. This paper therefore has strong links with the rural development theme of this conference.

Indeed, tourism is one of the largest and fastest growing industries in the world. In 2002 the UK tourism industry generated £75.9 billion (www.staruk.org.uk). Key growth areas are in nature-based and cultural tourism, as well as adventure and sports tourism. Forests are seen as having much potential in these growing markets. The Forestry Commission recently funded work which estimated that forest related tourism day visits are worth around £2.3 billion – that is over 3% of the total tourism expenditure in the UK (Hill et al., 2003). Whilst this is a significant figure it is possible to argue that it has the potential to be considerably bigger.

Given these figures and trends, we can see that it is important to understand current and potential relationships between forestry and tourism and to develop those relations to their full potential. Whilst some work, for example Forest Enterprise visitor surveys, has provided information on the consumption, or use, of forests by tourists, there has been little, if any, research which has explored the interface between tourism providers and forestry. The aim of the Leisure Landscapes project was hence, to work with tourism providers to try to understand tourism supplier issues. In particular it sought to investigate tourism provider perspectives on the values and uses of forests for tourism as well as to uncover their perspectives on current and potential relationships between tourism providers and forest managers.

Methods

The work employed a qualitative methodology and was focused in three study areas, the Great Glen in the Scottish Highlands, the Dyfi Valley in

Mid Wales and the Suffolk Coasts and Heaths in the East of England. Each area was chosen to provide a contrast in terms of the character of forests, socio-economic conditions within local communities and stages of development of tourism activities.

Tourism providers were split into two groups – strategic organisations; which were drawn from a range of different policy areas, for example land use management, tourism, sport and economic development and so on, and tourism enterprises; these were generally businesses but also included charitable and public sector organisations. Accommodation providers, managers of shops and pubs, sports activity providers, suppliers of arts and wildlife watching activities as well as managers of tourist attractions were included in this category.

The views of strategic organisations were ascertained through in-depth interviews (following May, 1997), (around 10 in each study area), whilst the perceptions and activities of tourism enterprises were identified through discussion groups (following Burgess J., 1988). Within each study area three discussion groups were held, one for providers of accommodation, pubs and shops, another for sports activity providers and one for suppliers of interpretation centres, arts and wildlife related activities.

Results and discussion

Values and uses of forests for tourism

Strategic organisations tended to emphasise tourism values which arise from the technical qualities of forests. In particular they spoke of their visual screening and noise absorption qualities, their robustness and ability to be used in a wide range of weather conditions and throughout the year. As such they were seen as being spaces which could be used by relatively large numbers of people and for a wide variety of tourism activities. Their potential to be used for noisy, visually intrusive and physically destructive uses was commented upon – especially because this was felt to stand in contrast to the ability of many other countryside habitats to accommodate such uses. The appeal of forests to visitors during the shoulder seasons in the tourism industry (autumn and spring) was also highlighted. We can speculate therefore that the forestry sector has the potential to increase the social and environmental acceptability of tourism as well as the economic sustainability of tourism businesses. This could occur through the promotion of forests for a wide diversity of tourism uses in a variety of weather conditions throughout the year, as well as through their utilisation as spaces where tourism activities can be channelled so as to reduce their adverse social and environmental impacts (for example, trampling of fragile habitats, noise and visual intrusions) in the wider areas in which forests are located.

Tourism enterprises tended to emphasise the economic benefits of forests and in particular how they can motivate people to visit areas where they are present, extend the length of visits as well as to prolong the tourism season. These values were seen to be related to three key features for forests: their imagery, the access they provide to the 'natural' environment and 'wild' space, as well as their man-made products and services. In terms of imagery, forests were seen to have the ability to create aesthetically attractive (green, colourful and beautiful) tourist destinations. In the Dyfi Valley this was due to the sheer extent of the forests. In the Great Glen, however, it was the way in which the forests blended and contrasted with the lochs and mountains, and in Suffolk, the way in which they merged with the lowland coastal heath, which was seen as critical in them creating an appealing tourism destination identity and experience. We see therefore that it is not necessarily the size of forests which determines their impacts on tourism, for the way in which they are designed and integrated with surrounding land uses to contribute to the overall landscape aesthetic, is also critical. The need for a stronger focus on landscape design to achieve this integration and improve aesthetics was advocated by many enterprises.

The access forests provide to 'green' and what many people perceive as 'wild' space was also highlighted as being an important tourism value of forests. Tourism enterprises spoke about the importance of being able to experience plants and animals, the sights and sounds of the forest environment. Activity providers especially emphasised the value in being able to roam freely away from trails and experience the 'wildness' or 'naturalness' of the environment. It is important therefore, that forest management for tourism pays attention to feelings of naturalness and the availability of non-timber forest products as well as the more traditional forest tourism products such as trails and visitor centres. This will require land managers and other decision makers to think broadly about forests as resources for tourism.

Tourism providers also discussed the importance of man-made facilities such as walking and cycling trails, visitor centres and car parks, as well as services such as guided walks. There was a feeling that the quality of these features is strongly related to condition of the natural environment in which they are located. Concerns were expressed that as forests are developed for tourism, the quality of the natural environment may be eroded. This suggests there is a need for research to promote understanding amongst forest managers about the appropriate balance between natural and man-made resources in different situations for different customers.

We see therefore that tourism businesses attach a diverse range of values to forests, and in turn, these are exploited through a range of direct and in-direct uses. Direct uses take place in forests and utilise, for example, forest aesthetics, natural and man-made products. They include the use of trails, car parks and picnic sites and the viewing of wildlife. Indirect uses do not take place in woodlands but through the use of images, textual and verbal references, refer to the presence of forests, their natural and man-made products and services.

As discussions with enterprises developed, it was clear that their uses of forests was not just a function of their core service (for example, accommodation provision) but reflected the broader range of products and services they supplied. So it was not necessarily the case that accommodation providers were in-direct users and activity providers direct users. For example, an accommodation provider in the Great Glen discussed the way in which he went into the forest to collect leaves from different trees and scanned them into the computer to produce interpretation guides for his visitors. Another discussed the way in which she used forests to gather blackthorn berries to make sloe gin (an alcoholic drink) to serve to her customers and how this helped to sell the nature-based element of her holiday product. We see therefore that it is more accurate to refer to direct and indirect *uses* rather than direct and indirect *users* of forests. This, in turn, emphasises the importance of forest managers engaging with enterprises at the local level to understand uses of forests and the need to be flexible in approaches and responses to the needs and aspirations of tourism providers.

Relationships between forest managers and tourism providers

There were very mixed levels of engagement with forest managers amongst the tourism providers who participated in the study. A broad range of providers however shared a desire for closer working relationships with forest managers. It was felt this would enable the sharing of a wide range of resources for the tourism development of forests and enable managers to move beyond currently narrow, financially grounded, perceptions of their associations with tourism enterprises (in other words they focus on charging enterprises for use of forests).

The value of partnership working was stressed in the planning, provision and marketing of products and services. In relation to planning, more open and inclusive processes were advocated so as to enable an exchange of knowledge and information to maximise the delivery of benefits, for example identify opportunities for business development, and reduce conflicts of use, for example between timber production and tourism or between recreational user groups. It was discussed how forest trails could be designed so they link with products and services such as accommodation, shops and pubs within the broader landscape in which forests are located. There was also a feeling that greater use could be made of a wider range of people and processes to distribute information on forest tourism opportunities. Forest enterprises especially emphasised the potential of their own role in the marketing of forest tourism: as one commented – 'we talk to customers, we act as a tourist information service, we tell them places to go'. The potential for providers and tourists to give time and energy towards the maintenance of leisure facilities was also raised. As such partnership working was seen as having the potential to increase the diversity and depth (meaning) of visitors experiences as well as improve the accessibility of forest tourism products and services.

Leisure landscape approaches to forest management for tourism

We can conclude that forests can motivate visits, prolong the stay of visitors and extend the length of the tourism season. As such they can contribute to the success of tourism businesses and the competitiveness of the tourism sector. According to enterprises, their impacts on tourism area identity, access to 'natural' and 'wild' space as well as man-made products and services are especially important. Strategic organisations on the other hand emphasised the technical qualities of forests and their ability to mitigate negative social and environmental impacts of tourism activities in the broader areas in which they are located. We see therefore that is not just the size of forests which is important in determining their impacts on tourism, for the availability and quality of many of the values of forests for tourism are strongly dependent on their design as well as the way in which and the degree to which they are integrated with surrounding land use planning processes.

The research also revealed that tourism providers consider the social (as well as physical) integration of forestry within the broader areas in which they are located as being important in the delivery of benefits for tourism. The importance of land managers and tourism providers working together to share knowledge, skills and other resources to plan, develop and market products and services was especially emphasised. Social integration would appear to be particularly important given that forest related tourism products and services are diverse, for example they constitute walking tours, craft items, foods and drinks as well as more conventionally cited trails and visitor centres. They are also delivered by a broad range of players, for example, accommodation providers, pubs and shops, activity providers and tourist attractions, as well as forest managers. The potential to create stronger products through the development of linkages between this broad range of providers (and thus products) was emphasised.

Abstracting these findings to a broader level, what tourism providers appeared to be advocating was a *landscape scale* approach to the design, planning and delivery of integrated tourism infrastructure and services. Within those landscapes, they seemed to suggest the need for development of *tourism and recreation networks* to integrate land uses, providers, their sites and products 'on the ground' but also 'virtually' through strategic planning, marketing, information provision and more in-depth partnership working. It was speculated that, in promoting an integrated approach to land use planning and management, these networks would enable a more holistic and efficacious utilisation of the resources of forests, the natural landscape and tourism stakeholders. It can be speculated that this would deliver economic development as well as social and environmental benefits by:

- *Improving the quality of experience of visitors* by enabling them to gain more diversity and meaning within a holistic tourism experience.
- *Enhancing the economic sustainability of tourism enterprises* through the facilitation of integrated access between countryside tourism facilities and businesses.
- *Improving the social and environmental sustainability of tourism areas* by guiding visitors away from tourism hotspots and sensitive natural environments, thus increasing the social and environmental acceptability of tourism.
- *Promoting efficient use of public money* by identifying situations in which infrastructure might easily be shared between recreation sites and providers.

Indeed, landscape scale approaches to spatial planning and natural land use management are receiving increasing attention from policy makers, academics and practitioners. The European Landscape Convention (www.coe.int/t/e/Cultural_Co-operation/Environment/Landscape/) is an important influence. The convention seeks to promote the utilisation and protection of landscapes to deliver a broad range of social, economic and environmental benefits. Quite clearly this will require an increasingly holistic conception and approach to forestry and land use planning, integrating a broad range of stakeholders, issues, policies and disciplines into sustainable land management plans. We can speculate that whilst the convention is focused on Europe, the utilisation of landscape scale approaches to land management are relevant to a broad range of natural environments in both marginal and proximate locations. However, if the potential benefits of such approaches are to be realised, there is a need for further research to explore the efficacy of land management processes and the design of forests as a means of achieving holistic and integrated approaches to tourism development.

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3.4 European network for long-term forest ecosystem and landscape research

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Introduction

The COST Action E25, ENFORS has its origin in the Ministerial Conference on the Protection of Forests in Europe (Strasbourg 1990) and later resolutions (Helsinki 1993, Lisbon 1998, Vienna 2003) on sustainable forest management. With 26 countries participating, the action started in 2000 and will be completed by the end of 2005.

This COST Action is the result of the work done by EFERN – European Forest Ecosystem Research Network. This action expands the ecosystem approach to landscape level, including socio-economic aspects.

The aim of the action

To develop the scientific base for and initiate a European network of sites for forest ecosystem and landscape research of relevance to sustainable forest management.

More specifically the overall aim can be identified in the following points:

- A pan-European network of field research facilities of relevance for sustainable forest management.
- A common scientific research programme/ strategy on forest ecosystems also focusing on the landscape level and the long-term perspective.
- A European database on field experiments relevant to sustainable forest management.

Defining and assessing sustainable forest management – SFM

During the past two decades sustainability has become a key term in emphasising the relationship between economic progress and the natural environment, explicitly addressing the ethical dimension and responsibilities we have towards future generations. Today conventionally three dimensions or pillars of sustainability are identified.

1. *Ecological* (or natural) sustainability defined as the long-term maximum use of a natural resource for raw material and energy, the capacity to decompose material, and exploitation of living organisms.
2. *Economic* sustainability defined in absolute value terms, derived from mass balances and economic feedback principles.
3. *Socio-cultural* (or social) sustainability defined as an inherent stability of social organisation and its components, the minimum requirements for system resilience to system oscillations, individual rights, limitations and duties for sustainability. It defines the gradient and driving forces necessary for society to remain stable, but still respecting individual integrity.

To implement SFM from political to user level a systematic procedure that includes four steps is proposed:

1. Defining indicators of ecological, economic and socio-cultural criteria.
2. Assessing criteria by combining indicators with performance targets.
3. Integrating complex information at multiple levels.
4. Communicating this complexity to policy and decision makers.

Defining landscape scale for the purpose of SFM

"Landscape" is used in the sense of landscape ecology and not for its aesthetical meaning. The interest is in ecological functioning in relation to forest management concerns and global evolution of the environment. Spatial and temporal scales are relevant because they fit both with those of management issues and of the ecological problems studied. Practically, ENFORS focuses on spatial scales from stand to ecological regions, and on time scales ranging from 1 to 100 years.

An ENFORS site has to be adequate to deal with management issues. Sustainable forestry also requires that multi-purpose utilisations be considered, which need to include social and economic aspects. A strong commitment with local forest managers is necessary, and a set of management experiments should be associated with more ecological studies. The ENFORS sites are thus not only experimental fields but also demonstration areas for sustainable forestry.

The network is built from existing experimental sites, most of them at stand level.

What is an ENFORS site?

The network of ENFORS field facilities are sites, on a landscape scale, where long- term data of various nature, supporting the three pillars of SFM, are available. The database includes information on biogeographical region, habitats, land use, socioeconomic situations and pressures, spatial scale, research activities and research potential for each site.

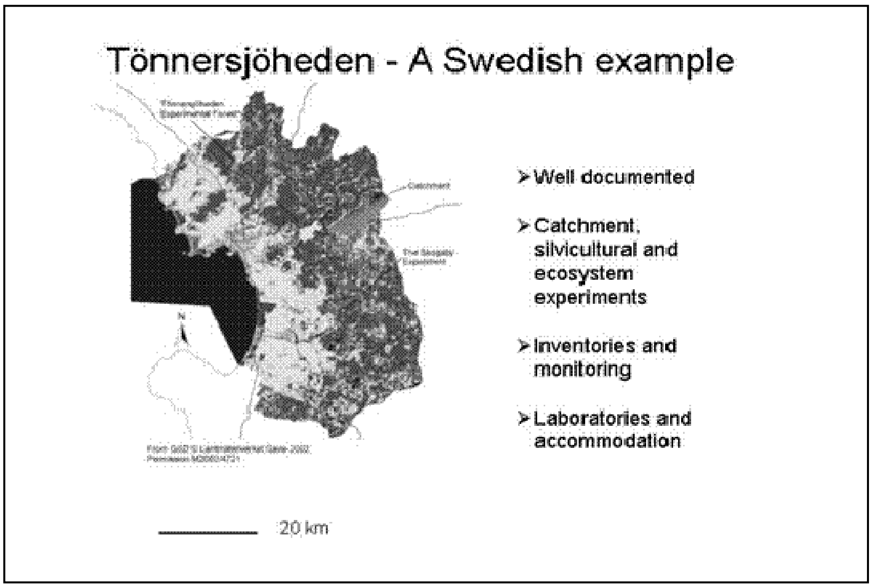

Figure 1. A Swedish example of ENFORS site

ENFORS field facilities

ENFORS has established a network of focal study areas for integrated approaches and multi-disciplinary forest research, which also act as meeting places for stakeholders on sustainable forestry and the role of forests in a landscape perspective.

The database is published on the website: www.enfors.org

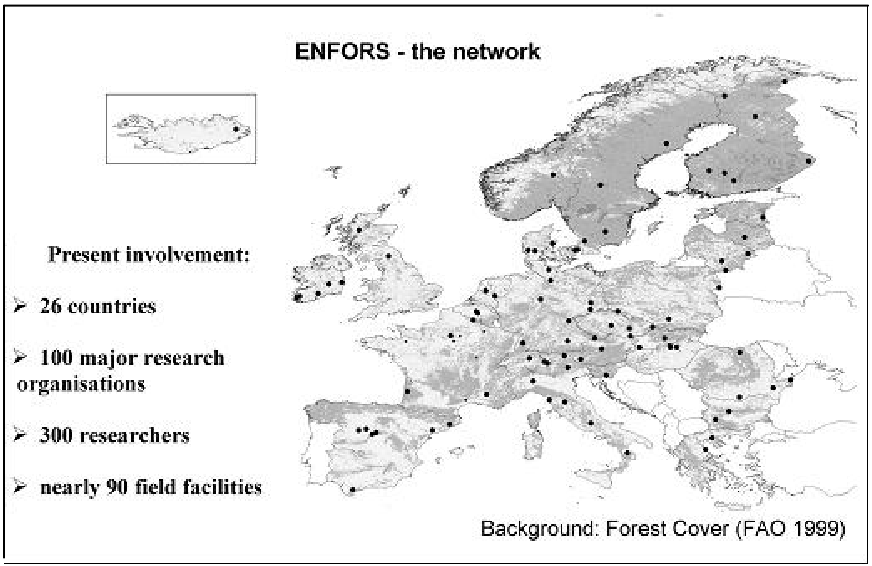

Figure 2. Overview of the ENFORS network sites

A research strategy – bridging the gap

ENFORS has elaborated a proposal for future research and development of SFM, where the starting point is criteria and indicators. "Landscape laboratories" such as the ENFORS Field Facilities are seen as an essential tool for implementing activities under two present elements: (fig 3)

1. The **P-D-P-M-A** –element aims at bridging the gap between policy and research through the elaboration of Predictions with development scenarios, synthesis of existing facts leading to Decision support systems serving as a base for establishing Policies. The policy decisions should lead to accepted Management activities, which need to be followed if being effective or not by Assessment activities.

2. The **R-S-M-** element aims at developing and maintaining the knowledge base through Research on the understanding of forest functions in real landscapes, based on proper knowledge of forests and its surrounding environment through Surveys and of ongoing changes and trends observed through Monitoring.

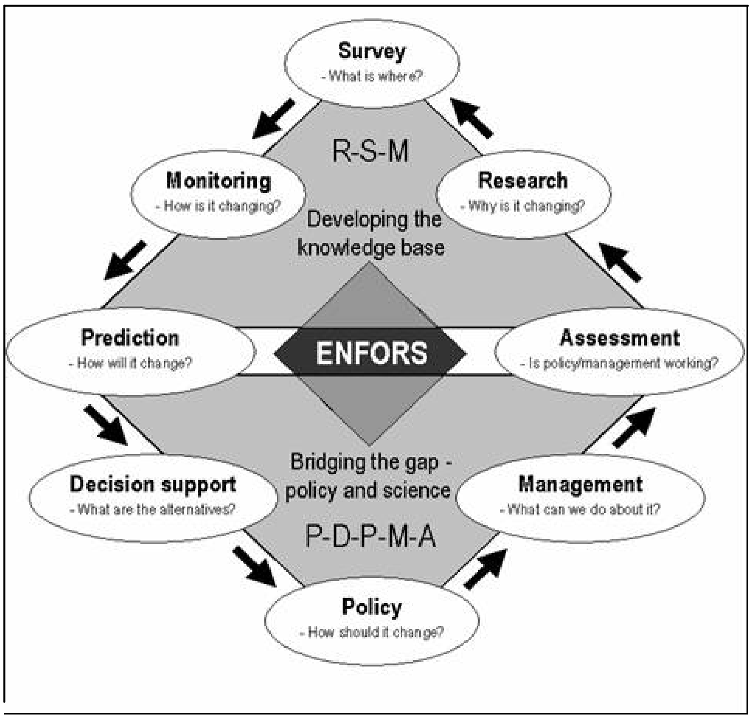

Figure 3. Schematic view of the ENFORS strategy

Publications and output of the COST action E25

Pathways to the wise management of forests in Europe (Führer, Andersson & Farrell 2000) – Forest Ecology and Management Vol. 132

Memorandum of Understanding & Technical Annex (Andersson et al. 2000)

Scientific issues related to sustainable forest management in an ecosystem and landscape perspective (Mårell et al. 2003) – Technical Report 1

Guidelines for the national inventories of field research facilities (Mårell et al. 2004) – Technical Report 2

European long-term research for sustainable forestry: Experimental and monitoring assets at the ecosystem and landscape level.
Part 1: Country reports
Part 2: ENFORS Field Facilities (Mårell & Leitgeb (eds) manuscript) – Technical Report 3 & 4

A research strategy for sustainable forest management in Europe. Developed by the European Network for long-term Forest Ecosystem and Landscape Research (COST Action E25) (Andersson *et al*. manuscript) – Technical Report 5

Towards the sustainable use of Europe's forests – forest ecosystem and landscape research: Scientific challenges and opportunities (Andersson, Birot and Paivinen (eds) 2004) – Proceeding from a symposium held in Tours, France June 2003. EFI Proccedings No. 49, 2004. 323 pp.

3.5 Afforestation in Iceland: The case of the land reclamation forestry project

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Abstract

Iceland has lost approximately 97% of its woodland cover over the last 1100 years, making it one of the world's most deforested countries. Limited forest cover and associated desertification is a major environmental issue. Diverse afforestation and land reclamation measures emerged during the last century. This paper explores the case of the Land Reclamation Forestry Project in the context of a transition from deforestation to afforestation. It provides a good opportunity to study various incentives, instruments and associated measures, impacting the implementation, progress and sustainability of an afforestation project. The experience from the project can contribute to other afforestation projects with similar objectives.

Introduction

The natural history of Iceland presents major changes in woodland cover. The well- recorded history of human settlement of the country 1150 years ago reveals changes in the woodland cover from around 30% down to a current cover of around 1% (Amorosi et al., 1997). Deforestation and associated land degradation and soil erosion are described as major environmental problems in the country (Robertson and Eysteinsson, 2005).

During the last decade, several afforestation programs emerged that challenge this situation. Deforestation has therefore been halted by relatively extensive afforestation programs. The same trend has been described for many other developed countries, with a large decline in forest cover, often for a relatively long period of time; then the trend reverses at some point, and forest cover increases (Rudel, 1998).

The passage from forest shrinkage (deforestation) to forest expansion (afforestation) has been labelled by Mather (2004) as "forest transitions". The idea of "forest transitions" asserts that stocks of forests change in predictable ways as societies undergo economic development, industrialization and urbanization (Mather, 1990; Walker, 1993; Mather and Needle, 1998).

The point at which the turnaround occurs has been labelled the "forest transition point", identifying the net woodland cover at the time of the turn (Rudel et al., 2005). This point differs between countries and can be associated with different factors and drivers where issues like agricultural reforms, rural exodus and urbanization, wood scarcity and evolving land use policies often play an important role (Mather, 2004).

Comments on the forest transitions in Iceland

The first afforestation trials were initiated in Iceland during the Danish colonial period. The earliest successful attempt to establish a forest was recorded in 1899 when a hectare of land was allocated to tree planting and direct seeding in Thingvellir in SW Iceland. Since then afforestation work has evolved to a current pace of around 1500 hectares annually (Robertson and Eysteinsson, 2005).

For establishing milestones in forest transitions in Iceland the most reliable data are the annual statistics of forest tree seedlings delivered from plant nurseries and regularly published. The largest step by far was taken around 1990, when there was a sharp rise in the annual seedling production from some 1.5 million seedlings to around 5 million (Figure 1).

The rationale behind this increase probably has multiple explanations. Agricultural reforms, economic development, increased environmental awareness, civil societal pressure, rural exodus, scientific achievements and empirical results from former plantations are factors identified in other countries and might all be relevant and contributing factors to those changes in the Icelandic context, as has been described for other denuded North Atlantic islands (Mather, 2004).

Agricultural reforms have been significant during the last two decades, impacting land use policies. The most prominent indicator is the number of sheep, calculated as the number of ewes. The number of ewes has decreased from around 1 million to a current level of around 500 thousand (Barkarson and Arnalds, 2001). This has had a significant impact on land use, especially land availability for forestry. During those agricultural reforms, there has also been a trend of subsidies having shifted from the traditional agricultural production sector to farmland afforestation programs. Now the landowners receive substantial governmental grants when planting trees on their own farms (Robertson and Eysteinsson, 2005).

Economic development has progressed in recent years. The GNP rise from 1995 – 2003 has been around 3.8% annually, which is around twice the average for the European Union (OECD, 2005). This has provided space for long-term governmental investments, hence forestry programs.

Increased environmental awareness and civil society pressure are interlinked concepts. During the 1970s and 1980s there was strong societal pressure for increased forestry and general environmental awareness which put a strong focus on the denuded situation of the country and lack of forests. A key contributor was the popular president of Iceland, Ms.

Vigdís Finnbogadóttir (1980–1996), putting afforestation on her agenda, exemplified by tree planting in her expeditions and receptions. The Friendship Forest, established in 1990, was initiated by her, and 22 heads of states have now planted a symbolic tree, making the site unique in the world. Recent surveys have shown that around 90% of the population want to see more forests in the country (Curl and Johannesdottir, 2005).

The Icelandic population is now the most urbanized in Europe with 92% currently living in urban areas. Exodus from rural to urban areas has been the trend over the last few decades, leaving land available throughout the country for new land use alternatives such as forestry.

An important issue when exploring the contributing factors to forest transitions are the emerging results from older forest stands and smaller experimental plots throughout the country which provide notable outcomes. Significant empirical results have contributed to the confidence and belief in forestry of Icelanders in general. Furthermore, many older forest areas have become highly popular recreational areas and increasingly demanded by the public.

These topics have probably all contributed to the sharp increase in new planting around 1990. However, further analyses of those interactions need to be done, identifying the most significant rationale behind the forest transitions in Iceland.

Current actors in afforestation

The increase in tree planting after 1990 has primarily been conducted through two mechanisms, the six regional Farm Forestry Programs and the Land Reclamation Forestry Program.

The Farm Forestry Programs are directed solidly towards private land owners and currently involve around 800 farm estates within the six regional programs. A land owner can receive up to 97% of the total establishment cost of the new forest through government funding, channelled via the regional programs, based on specific legislation (Robertson and Eysteinsson, 2005). Strong emphasis is placed on timber production, multiple use forestry, farm shelterbelts and to some extent on woodland restoration.

The Land Reclamation Forestry Program operates differently and will be explored further in the following section.

The case of the land reclamation forestry program

The Land Reclamation Forestry Program was initiated by the Icelandic Forestry Association (IFA) on its 60th anniversary in 1990 following a major awareness raising program. The project is executed by the Icelandic Forestry Association in collaboration with its 59 member societies, The Soil Conservation Service of Iceland, The Icelandic Forest Service and the Ministry of Agriculture, providing a multi-stakeholder collaboration between governmental bodies and non-governmental organizations.

The project focuses on denuded areas country wide, combining soil conservation, land reclamation and afforestation methodologies. It is currently conducted on 130 sites, generally having public land tenure and covering around 11,000 hectares. The project's objectives are restoration of the environmental services that woodlands provide, focusing on eroded, exposed and/or barren sites.

When sites are selected, public access is a key criterion. Furthermore, it is important to have a responsible local organisation involved, usually the local forest society and a willingness by the landowner to sign a long-term, rent free contract. Therefore, the majority of the sites have communal land tenure, in most cases from the local municipality. The sites can roughly be divided into two categories, extensive soil conservation areas in rural and more remote areas and smaller sites closer to urban areas. Currently, such sites are found on the periphery of all main urban areas in Iceland.

The project is executed and facilitated by the IFA. The government pays annually a lump sum to the IFA, now 20 million ISK or around USD 300,000, based on a renewable contract. This money is used to buy forest tree seedlings and pay for site planning and management. Local forest societies are responsible for the practical work locally and all other costs, such as acquiring land, fencing, planting, fertilizing, etc. A great deal of voluntary work is done, especially on "having things done", frequently in collaboration with local municipalities and other NGO´s. The grant from the project is therefore in the form of forest tree seedlings, which are delivered to each forest society.

The local forest societies are therefore the key actors in the project. Currently a network of 59 such NGO´s exists in the country with 8000 members. These societies are active in most municipalities, although they vary a lot in size and activity. The planting work is usually performed either by summer labour from the municipality, unemployed people, other NGO´s and/or by forest society volunteers.

As the initial objective of the project is to restore the ecological functions of forest ecosystems on degraded and exposed areas and by that create better a local environment, local actors are generally keen to actively participate.

Some key issues to succeed

Some issues can be identified that have facilitated the project achievements and contributed to its development and sustainability for the past 15 years.

Clear objectives

The project had clear objectives from the beginning. The objectives have however evolved, where recreation has become more and more demanded on many of the sites as the forest emerges. Allowing the objectives to evolve is important for such a long- term project, as afforestation is at northern latitudes.

Another issue in this context is the rising debate about CO2 emissions and global warming. The project started in 1990, which coincides with the reference time in the Kyoto protocol to which Iceland is a signatory. Therefore, the project's CO2 sequestration is fully calculated in the national carbon account.

Secured land tenure

The project has mainly operated on communally or governmentally owned land. This is a key issue when it comes to public participation and voluntary work. People are not willing to participate and lobby for land reclamation on land that is privately owned. But although the bulk of the project's reclamation sites have public land tenure, solid contracts are made to secure the project's and local forest societies' long-term tenure. Those contracts also ensure public access to the areas, contributing greatly to the general public consciousness.

Support from the local municipality

Working on land owned by the municipality has secured local support for the project, thus establishing mutual interest. The local forest society's interest is consistent with the municipality's interest. Support from the local municipality is also vital in the context of site planning, as the municipalities have the mandate of land-use planning within their boundaries.

Secure financing

Large scale afforestation projects need to have secure, long-term financing. In the Land Reclamation Forestry Project the governmental finances are based on a renewable five year contract. This is highly important as seedling production needs to be planned in advance and to insure reliability when making long-term land contracts. A five year time span is the absolute minimum in this context.

Professionalism mixing with enthusiasm

Obviously, such a project has to be based on professional advice and the best available knowledge. As that competence can hardly be established in all small societies, education, courses and information material have to be provided. Furthermore, clear and easy-to-understand forest management plans need to be produced. But it is also our experience that in addition to the necessary professional backup, enthusiasm needs to be fostered, something that plays a key role in the sustainability of such a project. As there are minor monetary incentives, it is necessary to establish local "ownership" of the project. In that context, the local forest societies play a key role, as the reliable and visible local partners. It is also within these societies that professionalism meets the enthusiasm of the locals, as local knowledge builds up and is passed on through empirical experience. Their local role secures the long-term sustainability of the project.

Current main challenges

However, the project is facing several challenges.

There are labour constraints in the inflated Icelandic economy. Also, school vacations are becoming shorter, making fewer youths available for summer employment in the municipalities. Labour skills have also been a constraint in the project.

There are also financial constraints, as there has been a greater demand for seedlings than the project can supply. In addition there are arriving challenges in pre-commercial thinning in some areas which the project cannot support.

Lastly, land constraints are a rising challenge. Land value has escalated in recent years, with a 5–10 fold rise in farm estate prices. Furthermore, competing interests for communally owned land make it a daunting task to negotiate more land for afforestation in many areas. Consequently, reluctance to sign long-term contracts is increasing.

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3.6 Tackling the ubiquitous wind

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Introduction

During the last two decades there has been a gradual shift to more participatory strategies, community involvement, and ecosystem management for multiple benefits of soil protection, recreation, aesthetics, shelter, economic, etc. These changes have greatly increased community involvement in projects, stimulated conservation awareness and improved land use. The ties between agricultural policy and soil-conservation issues are also being strengthened by a 'bottom up' approach modelled on the *'Farmers Heal the Land'* and *'Land Care'* programmes which recognize land users as the true custodians of the land, providing them with incentives through the *'Better Farms'* planning programme for soil conservation and allowing them to forge a new relationship between those who create and use scientific knowledge and those who support and finance it, and those concerned with its application and impacts. (Arnalds 2005). This quantum shift in policy from "*the land they use*" to "*people who use the land*" is especially important in shelter wood planning and establishment since, the "*people who use the land*" are cognizant of many environmental indicators of the wind effects on '*their*' landscape which, in terms of the scientific method, would be deemed an untestable hypothesis – but are real nevertheless. To Icelanders, activities such as shelter wood planning, design and establishment are as much about art, aesthetics and cultural values as they are of science and technology. So it is natural to combine traditional knowledge of environmental indicators of wind effects on trees with scientific advances. It is in this context that this paper addresses the role of wind in the landscape by combining basic scientific principles with traditional knowledge of the interrelationship between wind and shelter woods in urban and rural landscapes. .

There is no shortage of examples of how successive generations of Icelanders have successfully tackled harsh, degraded landscapes. One of the best examples of the fortitude, foresight and native intuition is reflected in the history of dyke building by many generations of Keldur farmers that helped to contain the desert and bring the farm from near ruin back to a productive landscape and preserve an ancient farm that is of a great historical and cultural asset to Iceland. On that point David Oddsson, then Prime Minister stated it well in this extract from his speech on National Day, June 17, 2003:

The interest and dedication that Icelanders have shown in undertaking all kinds of cultivation and forestation under tough conditions in recent decades have produced rich results. Patience and obstinacy have been rewarded. And when the world is as mild as it has been this spring, there are impressive areas of vegetation, gardens, shelter belts and woodlands to welcome it. Success breeds determination, and now is an ideal time to make a special effort by cultivating, planting and fostering vegetation and the natural environment.

However, ornate trees and dells do more than please the eye when nature is in bloom. They may serve as a reminder to us of other unrelated things. Firm trees with proud crowns do not grow and flourish unless their foundation and roots, which are nonetheless hidden, are powerful and active. The leaves that stretch skywards and draw their energy from the sun are one condition for a tree to grow and flourish, and the roots are the other. The same applies to our country and the nation that inhabits it. The history and soul, language and feelings, and not least the determination, selflessness and strength of mind of the many people who made their contributions without ever doubting them are the roots on which Iceland today and its worldly success rest. We rejoice at the fine weather. And although we know from experience that the weather is ever-changeable, we do not need to fear this any more than the branch of Icelandic birch that the poet addressed with the words

> You need not fear, my birch, the colder days:
> you can turn darkness and the rocks and screes
> to a leafy cape that in the morning breeze
> lifts in trembling homage to the heaven's rays.

Shelter structures

The construction of stone dykes and turf walls dates back to the settlement era. For example, in 1193 a 6 km dyke was built from Keldur to the River Rangá and some ancient dykes at Keldur may have been built between 1200–1300 to protect the barley fields (Vigfús Gudmundsson,1946).

Historically much of the district of Rangárvallahreppur was once a wooded delta of birch, willow and rowan and from medieval times until the mid 19th century had a much larger extent of productive grassland. In 1776 the Danish King decreed that turf walls be built around all hay fields in Iceland to protect them from grazing. But the Keldur farmer and his neighbouring ‘sand farmers’ ignored the decree on the grounds that cutting turf would start and/or accelerate wind erosion on their land. Nevertheless, the *Annals of Rangárvallahreppur* -1778 record that of 52 farms 32 had turf walls varying in length from 1 – 146 fathoms (1.83 m – 263 m) and in many cases 3–5 fathoms (5.4 m – 9 m). Whether it is related or not to turfing, by early 19th century erosion had become serious enough that in1849 Gudmundur Brynjólfsson of Keldur began building the ‘*Eastfield dyke*’ to prevent an erosion escarpment from extending into his hay field. The lava stone dyke was 60 fathoms (108 m) long and 2 ells (1 m) high and sturdy enough keep out or enclose cattle. Gudmundur’s son Skúli Gudmundsson (1862–1946) continued the work of his father and was renowned for his outstanding work in building dykes to combat the '*sand demon*'. He considered 1882 as the worst year of them all for sand drifting when the farm houses were almost being covered entirely by the sand and the hayfields were level with sand and some of the livestock houses filled up.

In 1926 the Soil Conservation Service erected a 5180m long barbed-wire fence enclosing some 108 hectares. This broad strip of land was seeded with lyme grass on the northeast of Keldur that stopped the sand drifting onto the hay fields. In 1967 most of the eroding land North of Keldur was enclosed by a of 40 km fence enclosing some 4250 hectares of land (Runólfsson, 1987). Skuli Lýdsson, the present farmer at Keldur, using a combination of traditional organic manure and modern fertilizers has reclaimed much of this vast estate to grassland and in so doing has positively transformed the image of the landscape surrounding his farm houses. He has mapped the extensive dyke system with GPS and also restored the ancient traditional farmstead (which has the oldest building in Iceland). Within the last seven years, a large area has been seeded with Alaska lupin and interplanted with more than a million tree seedlings. Considering that the ruins of 18 farmsteads have been found north of Keldur, it is a remarkable feat for five generations of Keldur farmers to have rescued their farm back from the brink of ruin and transformed it into a productive farm with irreplaceable historical and cultural assets.

West of Keldur, the Bolholt farmstead succumbed to the desert and was abandoned for several hundred years. The Soil Conservation Service has restored much of the grassland at Árskógar (meaning river woods) and at Sölvahraun the SCS have used bales of hay to stabilize the drifting sand. When the bales break up or before sand covers them completely fertile humus builds up rapidly, which provides a niche for microbiota for naturally regenerated plants and a better chance for deep-rooted species of tree and shrubs to grow. In many cases restoration to grassland is followed by tree plantations such as those at Bolholt established by the Icelandic Forest Society of Rangæinga.

Afforestation at Gunnarsholt (headquarters of the Soil Conservation Service) a few kilometers west of Keldur) was started in 1939 when native birch (*Betula pubescens*) from Skaftafell was seeded in a sheltered area surrounded by lava flow and moraines. The birch thrived and is known as Gunnlaugsskógur forest. The birch garden at Gunnarsholt was transplanted from Gunnlaugsskógur. Establishment of the extensive linear shelterbelts started in 1959. They now extend over 60 km, sheltering fields for seed production of reclamation species of grasses and legumes. On average 1 km of windbreaks is added annually (Sveinsson and Sæmundsdóttir, 2003). The Gunnarsholt main shelterbelt network is judiciously spaced and oriented at a slight angle to the two most troublesome winds, i.e., the cold southeast wind (which reduces productivity) and the dry northeast wind (which can restart sand drifting). The advantage of angular orientation with respect to wind direction is that there is a greater 'sail area' that winds have to penetrate and thus more area providing shelter.

Fljótsdalur in east Iceland is not particularly windy – in fact, it has long periods of virtual calm. Without trees, the slow drift of an ocean breeze, or a down-valley breeze from the opposite direction, makes growing vegetables and barley unprofitable and discourages campers and tourists. The organic farmer at Vallanes, Fljótsdalur, has established a fine system of fast-growing, double-row poplar shelterbelts that enables him to produce high quality vegetable and cereals for which he gets top prices. He has purposely encouraged visitors to use the walking paths through his network of shelterbelts with a beautiful canopy of lofty, sweet-smelling poplars around the fields of barley and potato and 'lupine fallow' (a natural fertilization technique) with magnificent views of high mountains. In recent years he has changed his shelterbelts from a single species to mixed species to add diversity and roughen the profile. In addition, he is planting large mixed species woodland on poorer land. This change in shelterbelt design reflects his belief that his farm is as much an art form as it is an economic entity.

Virtually all tree planting within communities and around farmsteads is best classified as shelter woods. They are usually a mixture of birch, willow, rowan, Sitka spruce and Alaska poplar. Linear shelterbelts of low stature often occur within the shelter woods either as an under-story or hedges along streets and property boundaries. The circular geometric patterns of low shelterbelts in Miklatún are extremely effective and interesting as are the horseshoe appendages on the inside of linear shelterbelts planted in the 1930's at Laugardalur and those recently planted at Hvanneyri. In many cases, older linear shelterbelts have evolved into shelter woods For example, at Laugardalur the linear shelterbelt, which has some of the tallest trees in Iceland, was planted by Einar Hjartarson, an electrician with a great enthusiasm for afforestation. In 1985, Einar's linear shelterbelts and streets dominated Laugardalur Park. Fifteen years later, the landscape has been completely transformed with irregular patterns of mixed woods, curved streets and paths. The only vestiges of linearity are the short hedges for plots in the Botanical Garden and a small section of Einar's original planting – altogether creating a diverse and pleasant visual effect in winter and summer from the ground and the air. Reykjavik has the largest forest in Iceland and its suburbs, like most other communities throughout Iceland, also have their own forest on the outskirts. There are attractive treescapes within the towns, such as Akureyri – the garden city by the Arctic Circle – Selfoss, Ísafjördur, Hveragerdi, Borgarnes, Egilsstadir and Hvolsvöllur, to name but a few.

Visualization of wind

Landscapes are made up of spatiotemporal assemblages that are inherently evolutionary and historical and irreversible insofar as the sequence of events is not repeated precisely. The interaction of wind and trees is non-equilibria, simply referred to as *complexity* – i.e., the dynamics of change. These interlocking states include homogeneity (stable), periodicity, quasi-periodicity and spatiotemporal chaos. The onset of spatiotemporal chaos is symmetry-breaking; for example, the simple act of the Danish King's decree that all farms build turf walls may have triggered the massive sand drifting; a small contingent of insects which destroyed a shelter wood; or a parasitic bacteria can the trees to good health; strong winds can blow down shallow rooted species, while deep rooted species will occupy their space.

The problem with transient dynamics in relation to wind and shelter wood is that the most elegant mathematical expressions of turbulence in trees aided by the most powerful computers in the world cannot solve the Navier-Stokes equations for any but the simplest of turbulent behaviour. However, wind tunnel visualization models, using glass beads, sand, hydrogen bubbles, combined with digital imaging, have closed the gap between theory and practice. A simple way to visualize stable and unstable wind patterns in models in various shelterwood designs is to create dalalæda (ground or radiation fog) with dry-ice or liquid nitrogen and capture images of turbulent patterns with a digital camera. Dry-ice models reveal that Görtler vortices and von Karman vortices on many scales are among the most common patterns. Görtler vortices are stable horizontal helical roll vortices generated by spiral warming and cooling when, for example, the surface of a fjord is colder than the air mass (or vice versa). They are recognized by the wind-rowing of foam and surfactants on water, cloud bands, and the linear formation of deserts. The von Karman vortices are formed by an obstruction in the free steam airflow, such as isolated trees and small shelter woods, buildings, islands, and even horses with their rumps to the wind. Robertson (1989) illustrated the transient nature of turbulence in the progression from a treeless landscape to the gradual development from poor to effective shelter wood. What these simple visualization models reveal the gross over-simplicity of most standard shelterbelt recommendations advocating they be perpendicular to a 'prevailing' wind, 50% porosity and over-simplified and unrealistic wind profiles. The Icelandic topography and passage of frontal systems induces far more complicated wind regimes and design parameters

Effects weather on trees and woodlands

Despite all the environmental and socioeconomic influences that affect shelter woods it is remarkable that, over the past century, Icelanders have an exceptionally good batting average in establishing shelterbelts and shelter woodlands by direct seeding and/or planting (Blöndal and Gunnarsson, 1999).

At the time of settlement native birch forest occupied about 25% of the land. Today, it occupies less than 1% of the land. Most of it is tall scrub forest that Sigurgeirsson (2004) suggests is the effect of dysgenic selection due primarily to the degradation of high forest to scrub forest and greater exposure to harsher weather. Harsher weather has meant increased frost damage, deeper penetration of soil frost depth followed by serious frost-heaving, dry, wet, cold, strong and /or salty wind, greater loading by snow and ice, blasting by windborne ice crystals and sand grains.

Ólafsdóttir and Thorvaldsson (2002) highlight some problems concerning both natural conditions and social aspects, such as small farms on the limit of sustainable existence; low summer temperatures resulting in low primary production; rugged landscape, with deep fjords, narrow valleys and high, steep mountains; increases in the occurrence of land and sea breeze; and a lack of shelterwood that leads to strong funnelling winds.

The funnelling of winds is especially damaging to isolated, small plantations that "act like magnets for large amounts of drifting snow", as one forester put it. This is because they are obstructions to the free flow of snow of drifting across treeless landscapes. In larger plantations, especially those bordering a lake or bordering expansive grasslands and heath, high snow drifts often develop inside the edges of plantations resulting in comparatively minimal damage in the form a narrow band of deformed trees, whilst leaving the edge trees largely undamaged. Quite often plantations are established in the shelter of a building, a tall fence, a low escarpment, a small hill, etc. But when they start to grow above the shelter they become susceptible to wind shear – like the old larch in Skrúdur and a small grove of Sitka spruce in the lee of a hill in Höfn í Hornafjord which Einarsson (pers. comm., 2005) describes as having developed a "flat top and suffering from wind, salt, and nutritional deficiency."

The positive side of this phenomenon is that they hint at various types of shelter wood designs that act as efficient snow traps – such as the *Icelandic knot* (Robertson and Eysteinsson, 2002). The basic approach is to develop roughness profiles, both laterally and vertically, to induce ever-decreasing scales of turbulence to calm. Roughness is best achieved through the use of a mixture of coniferous and deciduous trees and shrubs with a much higher proportion of deciduous shrubs and small trees on the windward to reduce the upward entrainment of snow. Planting such a snow trap system on the windward side of a plantation or afforestation area can both reduce snow damage in the plantation itself whilst creating an attractive area for outdoor recreation that will eventually become the forest edge

Culture and aesthetics

Forestry in Iceland has six, only 4 hear, basic functions: ecological (ecosystem processes, habitats, wildlife); economic (wood production, non-wood products); protective (soil and water conservation, shelter, sequestering CO_2); and social (recreation, cultural and spiritual). The Icelandic Forest Service is guided by a broad set of policy goals and legal instruments aimed at protecting cultural landscapes notably the Environmental Impact Assessment Act no. 106/2000 and the Nature Conservation Act no. 44/1999 and even the Forest Service's own set of guidelines for afforestation planners (Eysteinsson 2004).

The definition of a cultural landscape is another example of transient dynamics because of an infinite variety of opinions that change with each generation or, more precisely, the population drift from the countryside to the major cities and towns. It is over-simplistic to say that: a) urbanites tend to value the landscape aesthetics, recreation and cultural pursuits; b) biologists perceive landscape in terms of biodiversity and habitats; and c) agriculturists value landscape mainly as a place to live and work. In truth there is a bit of urbanism, biologist and agriculturist in foresters who see landscape that needs upgrading. And a little bit of the artist, botanist, farmer and forester in all of us.

Iceland's environmental guidelines and the European Union's Landscape Convention expect a lot in a shelter wood design; besides, basic public comfort, convenience and safety designers must also include compatibility with cultural assets and preservation of 'traditional' landscapes. What this entails is a quantum shift away from relying on Euclidean geometry, based on the idealized simplicity of homogeneity and symmetry, fractal-based models that can deal with the myriad of scaling factors, lacunarity and heterogeneity inherent in a well-designed mixed species shelter wood. In addition we need to place more emphasis on circular statistics to properly account for the directional effects of winds regimes from all directions.

Biodiversity

Shelter woods have multi-purpose dimension; the less obvious attributes being they provide suitable habitats for soil biota, native plants and wildlife, they repair soil erosion, provide a warmer and less windy microclimate for less hardy varieties of vegetable and cereal crops. Among the more obvious and much appreciated attributes they shelter communities and farmsteads, are used for the conservation of genetic diversity and tree breeding, and because they have high aesthetic value in gardens, parks and arboreta they are prime recreational areas; they are a source of home-grown specialty wood for crafts and furniture, and are used extensively for educational and scientific study.

Of course, some shelter woods are more attractive than other. But by and large, the mixed species with roughened canopies and planted in patches with a fractal (irregular) pattern are by far the most functional in terms of biodiversity across many scales. It is understandable and perhaps human nature that we should aim plantations with the tallest, straightest and symmetrical trees – this is certainly the goal of timber production forestry.

Mixed shelter woods rich in biodiversity have become the norm in many communities in Iceland such as the treescapes in Akureyri, Selfoss, Ísafjördur, Borgarnes, Egilsstadir and Hvolsvöllur and the Laugardal recreational complex, to name but a few. What the treescapes in communities and the shelter woods on farmsteads have demonstrated over the past several decades is that trees for the purpose of shelter, aesthetics and timber grow best and are more robust in woodland mixtures than in the monospecific narrow shelterbelt strips.

Most people prefer that trees that are tall, have straight boles and symmetrical crowns. In fact there are trees that are superb by boreal standards. And certainly foresters and tree breeders with an eye on timber production justifiably select provenances and breed for that purpose; indeed, some of their trees are 20–22 m (and projected to reach 26 m). But the windier the locality, the rougher the trees become in the course of genetic adaptation. So in every provenance trial and breeding program, there are always ‘rogues’ with a rough form that normally get weeded out. However, in the context of biodiversity, i.e., conserving a diverse genetic resource, there is need for a rough profile in shelter woods that can make use of these ‘rough rogues’. From an artistic viewpoint, ‘rogues’ and weather beaten cousins certainly add a more interesting form and character to the landscape than the tiresome Euclidean perfection of elegant strains.

Geodiversity

The general wind regime of Iceland is characterized by long periods of relatively calm and light winds punctuated by the occasional gale. Some deep valleys in mountainous terrain hardly ever experience strong winds, while others get hurricanes force winds with violent gusts up to 35–40 m s^{-1}. As to what these gusts are like, an email dated Nov. 2, 2001 from a colleague noted, *"The SW wind was 35 m/sec. slamming up to 45 m/sec. I could hear from inside the house the screaming noises from the wind wrestling with Núpur peak – like a loud symphony –The Singing Núpur! It was frightening, but all are well, minus some doors here and there."*

Ágústsson and Ólafsson (2004) have analyzed gust factors in mountainous areas across Iceland in relation to atmospheric stability. In short, mountains within 8 km upstream of a weather station and at least 600 m above them are responsible for the violent gusts. Surprisingly, some of the tallest, best formed and oldest trees and plantations in Iceland are no worse for wear in areas with infrequent violent gusts.

Biophysical indicators are the best way to appreciate the influence of geodiversity on wind patterns. For example, Honami's (downward spurts 'cat's paws'), Görtlers (longitudinal gravity waves) and von Karman's leave their signatures on fjords, lakes, sand dunes, and in the directional profile of trees, shrubs, tussocks of grass, the growth habits and distribution of herbs, mosses and lichens. Northerly cornering winds are easily detected in the trees below the summit of Midhúsahyrnd near Reykhólar and similarly at Hafnarmellir. The ruggedness of old European larches at Hvannery, Skrúdur (below Núpur), and Stóra Sandfell in Skriddalur reflects their battles with cold winds and late spring frosts. Freezing rain, salt spray and surfactants have left their mark on Ísafjördur's trees and shrubs while a kilometer or so inland plantations are less affected. Both Hallormstadir Forest in east Iceland and Vaglir Forest in the north and Skorradalur Forest in the west are noted for low average wind speed and a high percentage of calm. Nevertheless, the birch exhibits detectable altitudinal gradient from more-or-less symmetrical crowns (mostly calm) to distinctly unidirectional asymmetric crowns mid-way up the slope due to diagonal upslope or cross-slope winds. Sigurdur Blondal (pers. comm., 1993) observed that, during bud-burst in spring, solar radiation from a low sun angle is sufficient to maintain temperatures above freezing which permits shoot survival on the south side of Colorado blue spruce *(Picea pungens)*; whereas temperatures fall well below freezing on its north side, which kill new shoots.

Shelter wood and architecture

On Thursday, October 26, 1995 a massive avalanche descending at speeds of up to 300 km/hr killed 16 people and destroyed much of Flateyri. To ensure this never happens again, a specially designed berm 20m high and roughly the shape of the letter A was built. To prevent erosion of the berm by wind and water landscape architect Pétur Jónsson teamed up with the West Fjords Farm Shelter Program to quickly establish vegetation on and around the berm and in the 40 ha of sheltered interior space that was developed for a memorial park. In addition dozens of enthusiastic volunteers from Flateyri and the Iceland Forestry Association planted thousands of trees and shrubs on short order. This magnificent structure is essentially a unique fast-response landscape project involving an interdisciplinary team of scientific researchers, technologists, administrative and financial institutions and, to cap it all off, landscape architects and foresters and volunteer tree planters from the Icelandic Forestry Association.

Another innovative multidisciplinary environmental approach is a suburban project design by the architecture and engineering company Batteríid Arkitektar's *Gjóla Tilraunaskipulag í Hamrahlíðarlöndum,* a designed suburb for 20,000 people. The conceptual plan is based on "Livable Winter Cities", ideals that focus on appropriate architectural design, street engineering and open space configurations to ensure maximum aesthetics and livability regardless of the weather. The underlying philosophy is that designing for winter results in a better summer environment. In the context of this paper, they designed a simple but somewhat unique shelterbelt which has gentle curved, being made up of overlapping small curves to filter the wind into fine turbulence patterns rather than tackling the wind head on and creating uncomfortable gustiness (as most linear shelterbelts do). In a way, this somewhat unique shelterbelt matches the buildings for the business section, which are also curved to deflect wind and snow.

Conclusions

Iceland is very much advanced in its holistic approach to local and national landscape planning. For over a century, it has demonstrated, with few exceptions, that effective shelter woods can be cultivated in most urban and agricultural districts. However, it is not enough for shelter wood designers and planters to concentrate solely on protection from the wind, snow and sand drifting; they must tackle the ubiquitous wind with an artistic flair which comes naturally through the use of fractal-based models that can deal with the myriad of scaling factors and heterogeneity inherent in environmental influences on shelter wood, and the need to preserve the integrity of the cultural and aesthetic landscapes.

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3.7 Inshore dunes afforestation operations of the North West Tunisian coasts

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Abstract:

The study concerns the identification of the endemic species characteristics of the chosen site, then the procedures of inshore dunes afforestation that use either exotic or indigenous species and their impact on the existing vegetation and the consequences to the site's inshore landscape and its ecological potential.

The site of Zouarâa is especially interesting because it is the only one in Tunisia to have high mobile dunes. The ecosystem of the beach and the dunes is very well preserved and it is one of the best in the whole Mediterranean. The fauna populations are rich. The plant cover is typical and similar to that existing in Atlantic coast dunes. There is also an important archaeological site identified by historical artefacts and ruins (former harbour and village, fossil forest) that are along the coast.

If the site shows evidence of a certain ecological and natural wealth, it is the object of various constraints and threats to the lack of maintenance of its environmental balance.

The efficacy of these afforestation operations of dunes by exotic species and their impact on the landscape and ecological level are discussed.

Keywords: Afforestation, coastal dunes, natural wealth, important forest areas

Introduction

The coasts of Tunisia are under big pressure from urbanisation and implantation by tourist associations and agencies. Today, more than 70% of the economic activities are based on the coastline, 90% of which is accounted for by tourist activities which have provoked several problems owing to the uncontrolled controlled development that threatens the ecological wealth and inshore natural landscape sites in Tunisia (Ramade F 1997).

The most common Coastal areas management problems are part of non-programmed planning activities, the decline of traditional sectors that do not pose a danger for the environment, and erosion (Rossi G 2000, Beatley T *et al* 1994).

Based on one well-known case study, that of the Zouaraa coast (MEAT, TDCMNR 1994) that represents one of the last Tunisian coastal natural areas, we'll develop the procedures of inshore dunes afforestation that makes use of either exotic or indigenous species in order to define the generated impacts at the landscape and ecological level. Thus, the analysis is concentrated not only on the natural landscape itself but also includes all other aspects that could affect it (cultural landscape, human occupations, etc.).

Coastal natural area of Zouaraa

Presentation

The Nefza-Zouaraa area located in northern Tunisia is in many aspects still pristine, not yet exploited for tourism. The wide beach, the complex dune system, the forest and the perennial river are remarkable from a naturalistic point of view (Bouju S 1997).

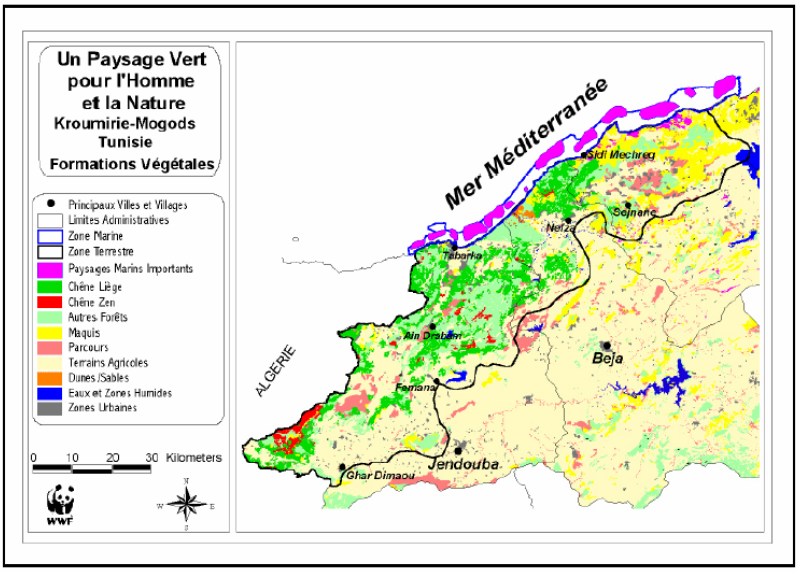

Figure 1. Floristic richness of Northern Tunisia (WWF 2002).

Geomorphology of the site

The studied area is characterized by:

- A wavy topography due to the wooded dunes of Zouaraa-Ouechtata-Nefza,
- A vast sandy beach because it's situated around the estuary of the river Zouaraa,

- The Zouaraa river has a relatively large valley that permitted the formation of a pond with variable salinity because it receives, according to the season, pluvial water or water from the Mediterranean Sea.

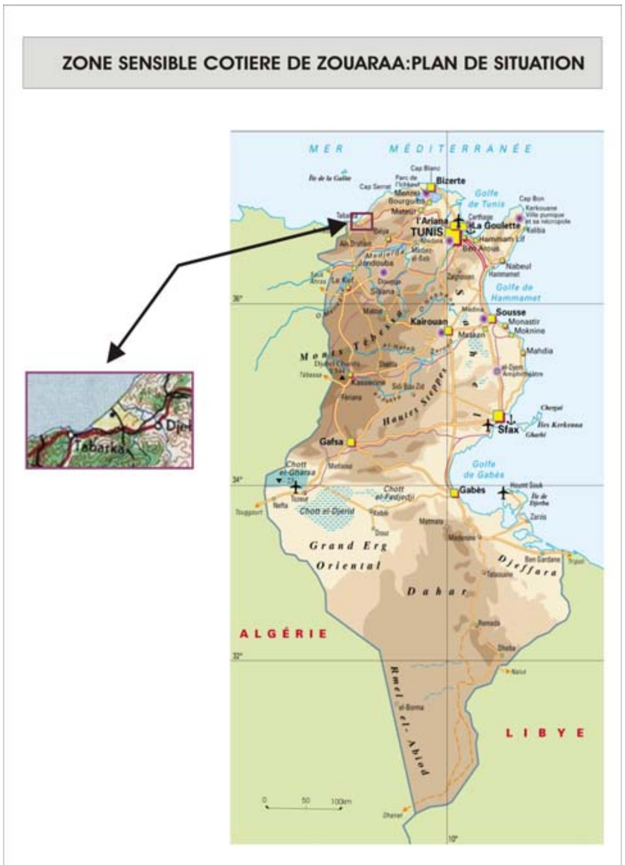

Figure 2. Location of the study area.

Characteristics of the dunes

It is a coastal zone characterized by coarse sand without a particular structure and where we can distinguish:

- Soils with little evolution representing dune material in the raw state where the fixing process of dunes by natural vegetation is always accompanied by soil development. We can observe this development on a larger scale and can determine it by following localization and surveying the different ages of the dunes,
- Soils evolved by the wind, localized on dunes having undergone an older colonization by natural or artificial vegetation.

Cultural landscape?

This part of the Tunisian coastline contains some important archaeological vestiges (Scapini F (ed.) 2002). Inside the dunes we can easily find artifacts and ruins testifying to a human presence during historic periods (as well as some prehistoric ones). On the right side of the River Zouaraa, immediately downstream from the dam, there is a vast ancient site whose structures are nearly completely buried under the present dunes.

Afforestation operations

Because of their tormented relief and their naturally skeletal soil, these dunes offer very few choices for agricultural enhancement, which justifies their appropriation by the local authorities and their inclusion in national territories since the end of the 19th century.

The afforestation operations began in the 1920s and are divided into three characteristic interventions:

The *first operation* of timbering was first undertaken in the beginning of the 1920s and was intended to stabilize the southern strip of dunes. The authorities had, indeed, settled on stabilizing a span of sand against the progression of sand that threatened to cut the line of the Bizerte-Tabarka railroad. Thus, 800 ha of dunes were forested to protect plantations of orange trees in Ouchtata at the same time. But this operation was only half successful because sand dunes along the beaches continued to be pushed inland by the powerful north-western winds.

Then a *second operation* consisted in planting a cord at the seafront in order to reduce the speed of the wind and to stabilize the moving dunes. But inland dunes continued to move and to represent a threat for the existing timber.

A *third action* has therefore been decided upon, consisting at this time of planting along the sea, a set of three cords in lines and, inside of these lines, cords of wattle. This action started in the 1970s, using grasses of *Acacia cyclops* from the coastline and *Acacia cyanophylla* from one kilometer back from the coastline. The advantage of these grasses is that they can be grazed and that they provide soft humus susceptible to leading to development of a soil on which it will be possible to plant *Pinus pinea*.

Afforestation operations near the dam (MEAT 1997)

Before the construction of the dam, the zone of Nefza appeared like a low and swampy zone largely occupied by the thick alluvia retaining clays from which emerge chalky massifs of 100 to 250 m of height.

Also, the living dunes formed in the north along the beach are pushed quickly toward the southeast and leads to the inshore relieves. Their progression is contained with difficulty by wattle coffer dams and various plantations completing the vegetation of *Juniperus sp*., *Quercus coccifera* and *Scrofularia sambucifolia* that already colonized the old dunes.

Figure 3. Afforestation operations on the north side of the River Zouaraa.

Forest exploitation

The intervention of foresters is summarized in three primary actions that don't necessarily require an entire "exploitation" (Hamrouni T 1985):

- The direct management of the dam according to priorities of agriculturists that are upstream and for which their need for irrigation water varies according to the level and the quality of the dam's water.
- The appropriate afforestation practices operations of inshore dunes all along the coastline of Nefza between the Rivers Zouaraa and Berkoukech.
- The systematic plantation of species of fast development parallel to endemic vegetation species to constitute a protective "umbrella" once it reaches a certain height and to constitute a useful branch reserve for the composition of useful compost.

Dunes classification

The dunes of the Ouchtata region cover a surface of about 100Km² and advance inland for 11 Km (Gottis C 1952–1953).

We distinguish 3 types of dunes: Fossil dunes, Fixed dunes and "Natural" dunes that aren't submitted to any afforestation operation:

- Fossil dunes: appear as the present dune migrations take a big extension in the zone of “Ragoubet Belkacem Ben Ali” and are prolonged at certain points out to the coastline.
- Fixed dunes: are fixed by the spontaneous forest cover of 25 km², the composed vegetation of *Juniperus sp*., *Quercus coccifera* or *Scrofularia sambucifolia* (MEAT 2000), thereabouts is delimited in its north border by the living dunes.
- “Natural” dunes: The present dunes that are formed along the beach and which reach about 20 m in height, are pushed southward by wind and are stopped only by the two rivers in the south.

Evaluation of the “important forest areas” relative to the dunes of Zouaraa

Methodology

This methodology was applied for the identification of the priority areas for forest conservation in the Mediterranean region based on three criteria:

- All endemic relic/rare forest types exclusive of the country.
- All forest types frequent in the Mediterranean region and that are present in the country only as relics.
- The “best” areas for the rest of the forest types according to the criteria listed below.

The evaluation process used to define the important forest areas is based on six interrelated variables with their own fixed indexes that are identified to be applied for the Mediterranean region. These variables are: Rarity, faunistic & floristic importance, maturity, wilderness, fragility and richness.

Results and discussion

The first observation is that the fixed dunes are especially composed of introduced vegetation that is responsible for the decrease of endemic species (E.Lee M 2003) (Table 1).

Table. 1 : Important forest area classification of the zone of Zouaraa.

Country : tunisia, site: zouaraa		
Ifa name	**Final score (10–100)**	**Number of importance**
Natural dunes	72.5	1
Fossil dunes	67.9	2
Fixed dunes	28.5	3

The exclusive use of exotic species in the afforestation operations affects the richness of endemic species by their rapid growth and adaptation (Bryan B 1998). On the other hand, the most important exotic vegetation species are present on the fossil dunes; however their high score shows that after a period of 50 to 80 years of afforestation operations that include some endemic species, the site has a tendency to regain its "natural state". But *Quercus coccifera* as an indicator of the final evolutionary stadium of dunes vegetation, which was used in the first operations of afforestation, is abandoned now because of the difficulties of multiplication and the low ratio of succeeding new plantations.

Conclusion

With a precise strategy of afforestation operations, we have a possibility to maintain the highest level of endemic species richness by temporary use of some exotic species that help provide conditions for their establishment.

However this process is too difficult because it requires (W Hwang S 1998, Baldwin A D 1994):

- developing a strategy for a long period of time;
- maintaining the application of all operations required;
- evaluating periodically the ratio of succeeding new plantations.

Knowing the fact that landscape factors were not introduced in the evaluation process of the important forest areas (PNUE/PAM/PAP 2001, Chouquer G 2001), it was demonstrated that this area is important at both ecological and landscape levels despite human intervention in the area since the beginning of the 20th century.

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3.8 The perception and relation between cultural and natural landscapes

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Abstract

The impact of afforestation on the landscape is varied and can influence perception in quite different ways. The interaction between culture-aesthetics-ecology and geology will be discussed with examples from Iceland, its culture and history. The paper reflects on the consequences of afforestation and the identity of landscape related to the past and to the vision of a future landscape and human behaviour. The discussion and dialogue between the "cultural" and "natural" landscapes are valuable and it is important to identify an agreement between afforestation and landscape based on culture-aesthetics-ecology and geology.

Keywords: Landscape, culture, history, perception, landscape values

Introduction

The impact of afforestation on landscape is varied and can influence perception in quite different ways. I will discuss how we experience and perceive landscape according to our culture and from the point of view of living in and with the land for centuries.

A great number of people are asking: What is cultural landscape and what is natural landscape? I will therefore address the answer to this important question. Furthermore I will try to point out the main factors involved in perceiving landscape and the value of agreeing on methods and management.

Landscape surrounds us everywhere and plays a great part in our well-being or lack of it. The changes that take place – quite often without our being aware of them – affect our lives. Examining why and how is important. Landscape is like a frame around us – within it is our life – our culture – our work and recreation. Research indicates that landscape is valuable and essential for us, and last but not least is a place to belong to.

Landscape is an interaction between nature and culture. Here in Iceland the geodiversity provides magnificent scenic views and at the same time is an important factor in understanding and explaining historical events and our complicated relation to our history as recorded in the sagas, and to our culture in general – and that is probably the main reason for how problematic it is to reach agreement on management of the land.

The landscape also represents and results from the difficult interaction between different professions and users – as, in fact, are theories about landscape.

To analyse and make an assessment various kinds of methods are used, i.e. aesthetic, based on "genus loci" (experience) or a physiological approach.

What is a cultural landscape – what is a natural landscape? Every landscape is a cultural landscape because the impact of man on earth is everywhere. Sometimes it is dominating but in other places it is almost invisible.

In different cultures we experience the understanding of landscape in various ways and with different glasses (Figure 1).

The following is a quotation from *Jala M. MakHzoumi from the University of Beirut in Lebanon:* "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.

´The outward movement' of perceiving 'landscape' as a scene that reaches its end in the horizon, is inevitably introverted in the Middle East. Nor is ´horizon´ as important a feature of landscape as it is in Western culture. Accordingly, the aesthetic meaning of ´landscape' in the Middle East is fundamentally different, physically, perceptually and symbolically, from the scenic, 'extrovert' historical and contemporary meaning of the word for people in the West." (J.M. Makhzoumi)

Now I want to point out the perception of various kinds of landscape at several time intervals and the influence on our culture in Iceland, with this question in mind: What has been the impact and has it mattered?

The year 1000 or the settlement

In Iceland as elsewhere, for centuries man and the land have been an entity and life has been concentrated on how to use and manage the land to survive. We can call it pragmatism, mere necessity. This approach has been with us from the time of the settlement of Iceland in the late 9th century on and has surely influenced the landscape.

The land was vegetated far more than we see today, birch and willows were prevalent. After the settlement, the natural environment changed in response to agrarian practices aided by the forces of nature themselves, above all the worsening of the climate.

The perception of the land shaped our culture and society from the earliest time. The settlers brought with them building traditions and domestic animals. Cattle were grazed in the forests. Over the centuries specific traditions evolved and were adapted to changes and the requirements of government at each time.

The sagas record the description of the landscape, not as related to emotions (susceptibilities), but to pragmatic potential, using expressions such as “big mountain, rivers full of fish, woods, and fruitful. Expressions like beautiful, hard, smooth and gentle did not exist in terms of the landscape and were simply not used.

Over time the perception of the landscape developed into a strong and extreme feeling for the sublime and mysterious – the unknown that lived in the landscape. The big, ugly and evil lived in the high, frightful and dark mountains, while in the green and grassy hills and the strange rocks lived elves and “hidden people”, little people in bright, beautiful clothes, and if their “houses” were protected and taken care of they were helpful and kind to humans.

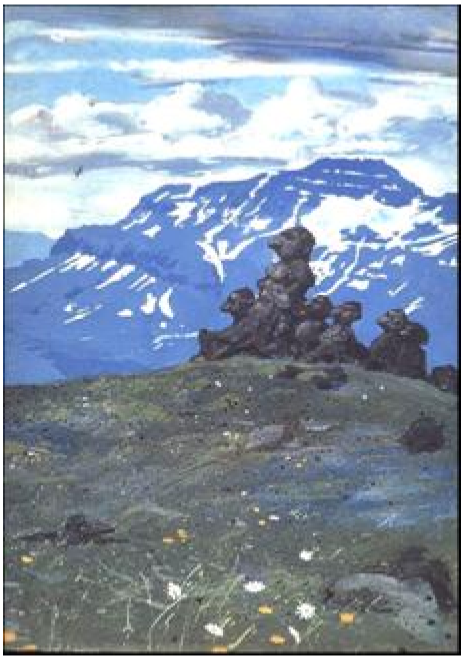

Figure 1. Strong belief in nature shaped by the landscape. (B. Pilkington; 1980. Ástarsaga úr Fjöllunum.)

Landscape as a term did not exist. The highlands were still dark, frightful and harmful to the population in many ways, and there were still the same goals of surviving: shelter and food.

For centuries the perception of landscape evolved as a one-sided use of land-housing, food and protection from the natural forces (the elements).

Figure 2. In 1600: Rural landscape and "natural" landscape - frightful and dark highlands

In 1900: The change to a romantic view and the development of nationalism

At this point in time poets and painters only expressed feelings for landscape as sunshine, bright light, singing birds, flowers are smiling at you and the little stream is singing a little melody for you – but still nothing about landscape in the highlands. There were no expressions, feelings about the extraordinary, the geology or the colours. These elements were totally absent.

Then a new generation of artists came on the stage and landscape came to be described as something extraordinary, beautiful – everything in nature was observed: colours, stones, vegetation – but just as an impression without any hint of pragmatic use.

We can use the famous Icelandic painter Kjarval as an example – the blue sky has disappeared and the eye is directed to the ground to the details in stones, moss and vegetation.

> "I´ll tell you the truth – stones are tame in landscape –
> pebbles are smiling – but that depends of course on
> who are passing by"
> (J.Kjarval)

"We should also think of the stones – we can not always
let them lie in our shadow – sometimes we have to
stroke them – listen to them and observe
what they are thinking !"
(J.Kjarval)

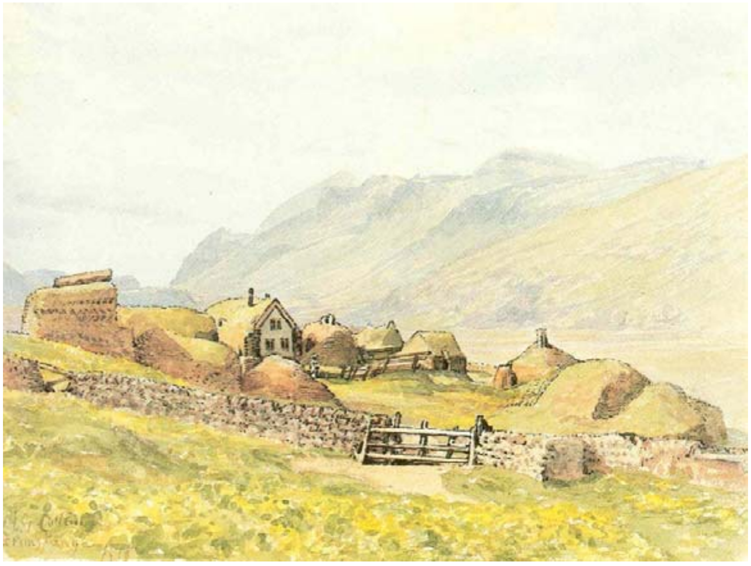

Figure 3. Farming landscape from ca. 1900 (Collingwood)

In 2004

How do we perceive the landscape in an ever-growing urban environment removed from the traditional uses of the land – with its meadows and harvests? Traditional agriculture is changing. Agriculture and traditional uses of the land are giving way to recreation. We are again faced with pragmatism but in a different way – urbanites now view the landscape with different perspectives – to fulfil their recreational needs.

Public perception of landscape seems to play an important role in Iceland as in other countries. Not only visually but also with the other senses like sight, smell and sound – all contribute to landscape appreciation. Perception is strongly affected too by cultural background.

Some predict that 90% of Icelanders will live in the capital region within 50 years. We are living in a time of tremendous change – new technologies – more powerful equipment – more knowledge – but it doesn't hinder us from manipulating the landscape.

Figure 4. Now landscape is magnificent – but we need more opportunities for employment: – it's a big country and enough "wilderness" left!

We redirect rivers, lakes, mountains. Change natural processes, digging dikes and cultivating the land in many ways.

This manipulation is needed so people can fulfil their needs and enhance their quality of life.

What is a valuable landscape?

It is probably valuable because we perceive it as fantastic when we lie in a hot tub despite rain, sleet, wind or snow and we can look across the landscape which was created by volcanic activity – which previously was hostile or sublime mysterious? Beautiful? or a threat to the inhabitants.

We also find the landscape majestic and impressive with an awesome geological diversity and the interaction of colours, structure and texture – we can use it to present tough "survival "tours, as on TV.

Some find the landscape ugly when it is eroded because of grazing – and overgrazing – while others have good and strong feelings about it – related to their happy childhood in a rural community.

And a lot of people like landscape with some kind of forest – as a shelter from wind – as a stimulus for recreation – and – you can even imagine that you are abroad!

And at last some would find the harlequin ducks on the River Laxá at Lake Mývatn as part of a fantastic ecosystem that needs protection, while others look at the ducks as one of many dishes in French cuisine.

Has the romantic view of landscape become merely history? And is the landscape of the future the kind of landscape that we want to use and exploit? It is not a landscape that stimulates the senses, as being majestic and a combination of different elements and natural forces, but a landscape for us to exploit and to enhance our quality of life and which can also help to increase our gross national product.

Strong relations to the past – the concept of Cultural Tourism is a key word in Icelandic tourism for the time being. Traditions and customs related to the landscape take on a new life when adapted to new recreational opportunities for tourism.

What images/experiences/traditions do we hand over to the next generation? I´m asking?

What to do?

As a result of my discussion I am coming to the point that most important for future afforestation here in Iceland is to work with and strengthen interaction between different professions and users – to accept different opinions and uses of landscape – and the relation between nature and culture.

Among others – the European landscape convention is one of the useful tools. The convention has been implemented in the other Nordic countries but not in Iceland.

Some of the recommendations from the Nordic project group are:

> "The multidisciplinary nature of landscape work makes extra demands on methodology and development work.
>
> This applies to the need to acquire adequate knowledge about:
>
> - what the landscape contains and means to us
> - what happens to it and why this happens
> - what we want the landscape to be like, and
> - how we are to achieve the objectives we set for the landscape and its development in the future"
>
> *(Nordens landskap; TemaNord 2003:550.pp.70)*

Earlier the use of the landscape and the mindset related to it had a relation to all people living in that community. Today we have a common goal and challenges to reach a consensus on the use and perception of the landscape.We need to set the strategies for the politicians. It is we ourselves who have the greatest responsibility to manage the land and reach a conclusion based on the Icelandic saying:

> Að fortíð skal hyggja...... "Think of the past when building the future. "

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4. Rural development

4.1 The role of fast growing tree species in the afforestation programme in Hungary

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Abstract

In Hungary, the increase of the forested area and that of the productivity and the improvement of the quality of the forests is still a determining social, economic and environ-mental strategic aim in the 21st century. According to the new Hungarian national afforestation plan about 700 thousand hectares of abandoned agricultural fields are to be afforested in the following 50 years in order to increase the ratio of the forested area of the country from 19% to 24–25%. About 30 to 35% of the new plantations are to be established with black locust (*Robinia pseudoacacia* L.) and hybrid poplars (*Populus* cv.), mostly on the Great Hungarian Plain. Black locust covering about 21% of all forested area (about 400 thousand hectares) in Hungary can produce timber of good quality only on sites with adequate moisture, well-aerated and loose structured soil, and rich in nutrients and humus. Volume of black locust crops varies between 150 and 300 m^3/ha in function of yield classes at the age of 30–35 years. The role of hybrid poplar management (covering 6.6% of the country's forested area) will be increasing first of all on marginal site conditions with a rotation age of 20–25 years.

Key words. Afforestation, fast growing tree species, Hungary

Introduction

The total territory of Hungary is 93 032 km^2 of which about 1.78 million ha is forest area (around 19%). Areas with elevation of more than 400 m above sea level represent less than 10% of the land area. The dominant climate is continental with low precipitation. The state owned forests represent 59% and the private forests 41% of the total forest area. About 70% of the forest area is managed as high forest and 30% as coppice. The growing stock is 340 million m^3, the annual increment is 11.7 million m^3, of which 7.5 million m^3 are harvested annually. The distribution of the tree species is shown on Figure 1.

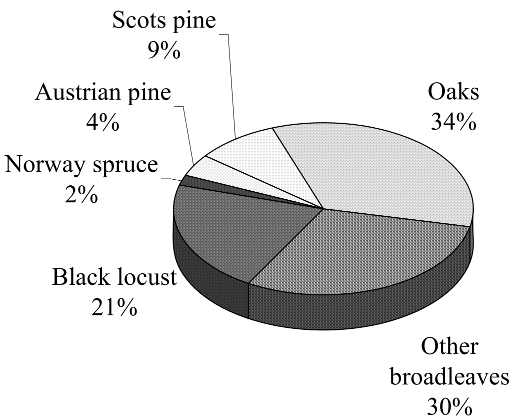

Figure 1. Tree species distribution in Hungary as a percentage of the total forest area

In Hungary, the increase of the forested area and that of the productivity and the improvement of the quality of the forests is still a determining social, economic and environmental strategic aim in the 21^{st} century.

The following issues are among the stressed objectives:

- The forest cover of our country must reach 24–25% by means of new afforestation in the first half of the 21st century.
- There must be around 700 thousand hectares of new forests planted on the lands not used in agriculture any more, meeting the requirements of rational land usage and regional development. This means the afforestation of 12–13 thousand hectares on aver-age per year.
- When taking into consideration the interests of area utilisation, regional and environ-mental development, and that of the economy, the role of the ecological factors must be determining.
- About two-thirds of the new afforestation will be realised on private lands, mainly on the Great Hungarian Plain where, first of all, we must consider fast growing tree species that can be grown in plantation: black locust and hybrid poplars.
- Let the usage of environment-friendly and recyclable forest products increase both in the agricultural and in the industrial sector.

It is a well-known fact in agriculture that making land utilisation more rational, and within this framework, new afforestation, will be an important factor in the future development of the region. It is also obvious that plantation forestry which improves the safety of growing and profitability can play a determining role in the forming of a well-considered and economical land utilisation system. This and the jobs provided by the relatively intensive tree growing can help increase local employment and deter people from migration.

Implementation of the national afforestation programme

Site requirements

Tree species for stand establishment (within the afforestation programme) are chosen according to their site requirements.

The Hungarian forest site classification is based on 3 factors, namely climate, soil and drainage hydrology. The natural range of tree species is generally influenced by climate and hydrology, while their growth is impacted chiefly by soil and, to some extent, hydrology.

Woodland in Hungary can be divided into 4 forest climatic types characterized by indicator tree species and forest associations, especially: beech forest type, hornbeam-oak forest type, sessile oak–Turkey oak forest type, and forest steppes.

Woodland classified as beech forest type covers about 9.5%. Main characteristics: the humidity is over 60% in July at 2 pm; the mean annual temperature is below 8–10 ºC and the mean annual precipitation is somewhat more than 600–800 mm.

Hornbeam-oak forest type accounting for 34.5%. The humidity here is 55–60% in July at 2 pm; the mean annual temperature is higher than 8 ºC and the mean annual precipitation is more than 600 mm.

Sessile oak–Turkey oak forest type covers 32.5%. The mean annual temperature is higher than 8–10 ºC and the mean annual precipitation is between 550 and 650 mm; the humidity here is 50–55% in July at 2 pm.

Forest steppe type covers about 23.5%. Closed forests occur only along the sides of rivers and on sites where there is an influx of groundwater. The humidity is less than 50% in July at 2 pm; the mean annual temperature is more than 9 ºC and the mean annual precipitation is less than 600 mm.

Programme-plan for afforestation on the Great Hungarian Plain

In Hungary the region of most importance for afforestation is the Great Hungarian Plain. The afforestation plan in the Great Plain development programme is the continuation of the planting endeavours of the last 100 years. This plan embraces the potential lands suitable for afforestation. It is based on the ecological and economic conditions of the 14 forestry regions into which the whole Great Plain has been divided, including all the lands suitable for afforestation in terms of their ecological (climate, hydrological and soil conditions) and economic character and the target forest stands too, by their dominant tree species. Through tree species, all afforestation technology is based upon well-defined site grounds (Führer 1998, 2000).

The basic principle for this programme is that only profitless farmlands should be considered for afforestation. On the grounds of their profitability, these arable lands have been ranged into three quality classes (excellent–good, medium and poor) and this classification has helped to find those suitable for afforestation.

In the programme, ecological and afforestation guide numbers and target stands are included, the use of which in time and space depends not only on economic and social possibilities, but which remain valid at any time for each forestry region. With the implementation of this programme, the rate of forested land on the Great Plain can be increased by as much as 8.7% (as can be seen on Figure 2).

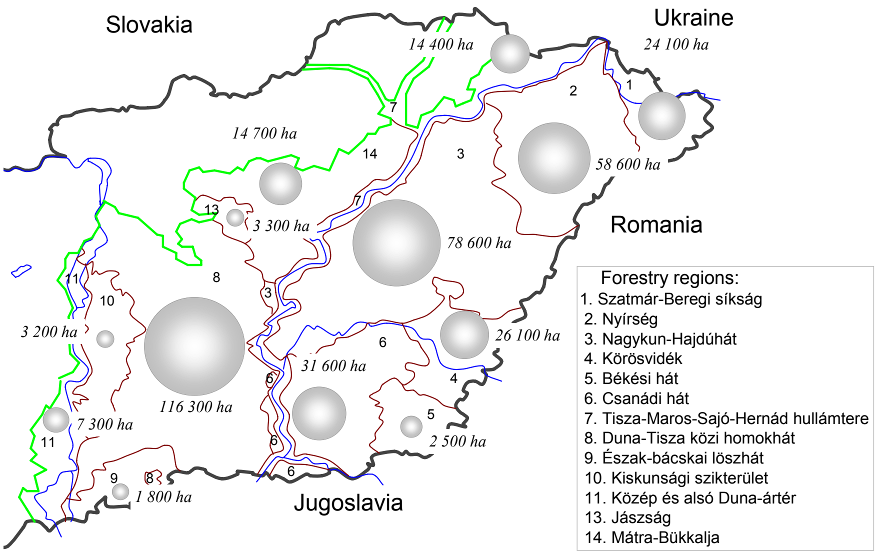

Figure 2. Afforestation potential on abandoned farmlands by forestry regions on the Great Hungarian Plain

This programme, with its ecological and economic aims, will promote the complex development of the Great Plain and serve the goals of wise land use policy and landscape protection.

The ratio of forested lands on the Great Plain will be 19.5%. The rate of forests within the forestry regions will also be raised in this level. The highest rate will be attained in the Nyírség (32%) and in the Duna–Tisza közi homokhát (33%) region, while the lowest rate of forests will be in the Kiskunsági szikvidék (4%) and Békési hát (4%) regions.

The role of black locust in the implementation of afforestation

In Hungary black locust occupied 370 000 ha in 1885, 109 000 ha in 1911, 186 000 ha in 1938 and 400 thousand ha in 2004. In other words, approximately 21% of all forested area in Hungary is covered by black locust. One–third of these stands are high forest and two–thirds of them are of coppice origin. In the 1960s, Hungary had more black locust forest than all the other European countries combined.

Black locust forests in Hungary have been established on good as well as medium and poor quality sites. Establishment of black locust stands producing timber of good quality is possible only on sites with adequate moisture and well-aerated and loose structured soil, rich in nutrients and humus. Black locust forest on medium and poor site quality are mostly utilized for the production of fuelwood, fodder, poles and props, as well as production of honey, soil protection and environmental improvements (Keresztesi 1988).

Therefore, the main aim of our new selection work is to find and improve black locust clones and cultivars, which perform good shape, provide good-quality wood material for industrial purposes, and which can adapt to the changing ecological conditions as well. As a result of our new selection programme 12 black locust clones *('KH 56A 2/5', 'KH 56A 2/6', 'MB 12D', 'MB 17D 4/1', 'CST 61A 3/1', 'MB 15A 2/3', 'MB 17D 3/10', 'PV 201E 2/1','PV 201E 2/3', 'PV 201E 2/4', 'PV 35 B/2' and 'PV 233 A/2')* have been improved (Rédei 2003).

Black locust afforestation and artificial regeneration can be established with seedlings. The most popular planting spacing for black locust in Hungary is 2.4 m by 0.7 to 1.0 m, requiring at least 4000 seedlings/ha. Black locust stands can also be regenerated by coppice (from root suckers).

According to available yield tables (Rédei 1984) the volume of the main crop varies between 80 and 280 m^3/ha in yield classes at the age of 30 years, which is the average rotation age for black locust stands in Hungary. The black locust stands of Yield Classes I–II have a rotation of 35–40 years and an annual increment of total volume of 12–14 m^3/ha/yr. The stands of Yield Classes III–IV have a rotation of 30 years and an annual increment of 8–9 m^3/ha/yr. Finally, the poorest stands (Yield Classes V–VI) have a rotation of 20–25 years and an annual increment of 4–6 m^3/ha/yr. In first generation coppice stands, growing stock, increment and health are similar to those in high forests.

The role of hybrid poplars in the implementation of afforestations

The importance of poplars is manifested by the fact that their proportion in the forested lands is 9.8% (the ratio of hybrid poplar is 6.6% – 120 000 ha), whereas the poplar timber volume felled is 19.6%. Workmanlike poplar growing started at the beginning of the 20^{th} century in Hungary. In the past 50 years several poplar planting programmes were implemented, the result of which is the present extent of poplars. The large-scale poplar afforestation programs led to establishing a certain part of poplar stands on marginal sites, resulting in poor growth. Conversion of these bad quality poplar plantations is part of the present agenda.

Poplar varieties grown in the first half of the 20^{th} century were*: Populus* X *euramericana* cv. Marilandica, cv. Serotina, cv. Robusta. Since the 1960s the cultivar '*I-214*' has become dominant in Hungarian poplar growing. From the end of the ‘70s on, new cultivars have been taken into practical use, some of which had been bred abroad and introduced to Hungary, while others were bred in our country. Of the last mentioned group the most common cultivar is *Populus* X *euramericana* cv. Pannonia, providing 50% of all the poplar planting stock (Tóth 1996).

Site conditions in Hungary are not very favourable for poplar growing, the reason why poplars are grown on marginal, far from optimal site conditions. Growing technologies were elaborated partly by learning from foreign experiences and adapting foreign techniques (of course, after careful investigation and experimentation). These technologies suit the special Hungarian conditions; however, many mistakes have been committed (e.g. too dense initial spacing, neglected prunings, etc.). The distribution of ownership of poplar-covered land is: state share companies 36%, private forest owners 56%, other 8%.

Research on poplars has produced several cultivars of excellent properties (*Populus* X *euramericana* cv. Pannonia, cv. Kopecky, cv. Koltay). Beside these the main task is the introduction of foreign clones and investigations on their adaptability.

The hybrid poplar plantations are established with mid-wide initial spacing from 4x4 m to 8x8 m, depending on the aim of production. They have a relatively short growing period (15–18 years) with high final yield on suitable sites (250–300 m^3/ha).

According to the site conditions and management circumstances 35–40% of the harvested timber is any of the thinner assortments. The target for the future is to raise the proportion of large dimension assortments (veneer and sawn logs), by which more profitable selling possibilities may be attained. Most of the poplar timber harvested is being exported nowadays as the capacity of the timber industry has not been enough for the processing of more timber. Therefore, one aim is to develop and expand timber-processing capacity.

Acknowledgements

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4.2 Forestry, rural development and innovation policy

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Abstract

Forestry makes a considerable contribution to rural development in many countries, e.g. by providing employment and income for rural areas, renewable resources for the forest sector, protecting nature and creating recreational environments. Innovation and entrepreneurship are widely recognised as the main driving forces for economic growth, competitiveness and creation of employment, which are also principal factors in rural development. Policies promoting innovation as well as entrepreneurship are key pillars of the EU Lisbon strategy, as well as principal development strategies in many countries. At the practical level, this means a slight shift from traditional investment subsidies towards incentives enhancing a knowledge based innovative environment. This paper discusses innovation concepts, especially from the point of view of the forest sector. Some of the few studies done of innovations in the forest sector are cited and compared to the author's experiences in the Ylä-Savo region in Finland.

Keywords: Small-scale forestry, innovation system, financial incentives

Introduction

Forestry has made a considerable contribution to rural development, e.g. by providing employment and income for rural areas, renewable resources for the forest sector, protecting nature and creating recreational environments. Innovation and entrepreneurship are widely recognised as the main driving forces for economic growth, competitiveness and creation of employment, which are also principal factors in rural development. Policies promoting innovation as well as entrepreneurship are key pillars of the EU Lisbon strategy, as well as principal development strategies in many countries. At the practical level, this means a slight shift from traditional investment subsidies towards incentives enhancing a knowledge based innovative environment.

Basically the concept of innovation means adapting to changes in time. There have been several changes in the forest sector in Europe, including new resources and suppliers (e.g. Eastern Europe), new technologies, new markets (e.g. carbon, energy) and changing consumer needs and demographics. Innovation can be defined in several ways, including renewal, which gives more turnover, lower costs or in other way that results in a better competitive advantage such as the successful introduction of novelties, or discontinuous intentional change in the inputs, outputs and processes of an enterprise. Innovation can also be defined as new combinations of knowledge which result in changed practices. It differs from invention, which means creation of something that has not existed before. The terms "innovation diffusion" or "innovation adoption" are used in looking at a sector or the economy as a whole. The process of innovation always includes social aspects, because the process itself is always interactive, e.g. in taking an innovation into practical use, acceptability and the diffusion of innovations. Innovation can be new to a firm or new to a market. It can be radical, or incremental. Product innovation may apply to goods or services, and process innovation may be technological or organizational (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

Innovation research has developed from a linear to a systemic understanding. The process of innovation is seen as non-linear and complex. A systemic research approach is concerned with structures, processes and interactions, and the functions of a system as a whole. According to Edquist and Johnson (1997), the functions of an innovative system are the reduction of uncertainties by providing information, the management of conflicts and co-operation, and the provision of incentives.

Why are innovation and entrepreneurship important? Because innovation is an engine for economic growth, competitiveness, income creation and business profits, creation of employment, especially in rural areas, changes towards environmental improvement and sustainable development, and also meeting changing consumer needs and demographics. This paper discusses innovation concepts, especially from the point of view of the forest sector. Some of the few studies carried out on innovations in the forest sector are cited and compared to the author's experiences in the Ylä-Savo region in Finland.

Research results from the forest sector

This section is based on the research results of the EFI Project Centre Innoforce (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005). To analyze the current situation of innovation in forestry in Central Europe and the role of institutional actors, the sectoral innovation system (SIS) approach was applied (Edquist 1997). Two types of surveys were conducted in order to investigate different stages in the innovation process of firms and their embeddedness in the innovation system: surveys among forest holdings and among participants in the institutional systems. The forest holding surveys were conducted in seven Central European countries: Austria, Germany, Czech Republic, Hungary, Italy (Trento Province), Slovakia and Slovenia. Response rates ranged from

25% (Slovakia, mail) to 100% (Slovenia, face-to-face). The total number of valid responses to the forest holding surveys was 1417.

The institutional level surveys were undertaken in six countries: Austria, Czech Republic, Hungary, Italy (Trento Province), Slovakia and Slovenia. In total 115 participants were interviewed (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

The forest holding survey results show that the context and conditions under which forestry is operating are in many respects not supportive of innovations: forestry is small-scale, not full-time work, minor incomes from forestry, "business as usual" is the dominant strategy. On average, nine percent of the forest owners/managers in Central European countries have introduced one or more product or process innovations in the last 3 years (1999–2001). Of the forest holdings of >500 ha more than half of all forest holdings had introduced innovations during this period. All of the innovations were "new to the firm"; however, none was "new to the market" (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

A key factor for innovation activities is access to information about possible innovative ideas and related further detailed information. The survey results for innovative forest holdings showed that information to implement innovation projects most often came from outside the forest holding. About two thirds of the ten most important sources were from outside the forest holding and from other than foresters or customers. Of all the sources, respondents named those that implied direct personal contacts more frequently than those that did not require such contact. This might indicate a high importance of customized information provision and a clear preference for information transfer arrangements that allow dialogue and interaction (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

The survey results for innovative forest holdings showed that, contrary to the source of information, the impulse for innovation most often came from inside the forest holding, i.e. from employees, owners or managers. Persons within the holding were decisive for pushing almost half of the most important innovation projects forward (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

Innovative forest owners and managers were asked to state, out of a list of factors based on the innovation system model, whether each of the factors played a role in the implementation of the most successful innovation project they had conducted over the preceding three years. The by far most important supporting factor named was vertical co-operation, primarily with suppliers, customers and other services, identified by more than two thirds of the respondents, on average, across countries. Innovative forest holdings were also asked to identify the factors that most impeded innovation that they had encountered when implementing their innovation project. They stated that the factors that most hindered their innovation projects were internal to the firm, at firm and personal levels. Most often, the impediments identified were problems of costs and of financing innovations, the risks involved and how to run operations differently (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

To measure the outcome of innovations to the forest holding and to determine the success of innovations participants were asked whether the innovations introduced in the preceding three years had resulted in a positive, neutral or negative effect on the operating result of the business. The results showed that on average 82% of such concrete innovation projects resulted in a "very positive" or "positive" outcome for the operating results of forest holdings; 15% of forest holdings reported that the outcome of the innovation was neither positive nor negative, whereas only 3% reported a more or less negative outcome for the performance of the forest holding (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

According to the classification of Edquist and Johnson (1997) three basic functions are fulfilled by innovation systems – either through explicit policies or implicitly: reduction of uncertainties by providing information, the management of conflicts and co-operation, and the provision of incentives. Forestry agencies are important providers of forest-related information. Giving advice is the most prominent service that forestry agencies provide – be they authorities or interest groups. The results of the case studies on innovations have particularly revealed that the institutional actors provide good information on traditional forestry topics but that information has been severely lacking on new market fields such as tourism, nature conservation, etc. (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

Concerning conflict management and co-ordination the picture is quite similar to the provision of information: Re the co-ordination among forest owners (i.e. in their traditional core competence area) the institutional actors do well. Concerning co-ordination with actors from other sectors, however, they fail. Political programmes that are relevant for innovation in forestry often have a strong focus on financial incentives. At the same time, as these programmes are usually not designed from the standpoint of support of innovation, they do not explicitly consider principles of innovation policies, e.g. to systematically support new and risky projects or to limit the support to the starting phase (see e.g. Rametsteiner and Weiss 2005, Rametsteiner and Bauer 2005).

Ylä-Savo region

The Ylä-Savo region is located in central Finland and is the northernmost part of the province of North Savo. Ylä-Savo consists of the town of Iisalmi (21 000 inhabitants) and the surrounding rural districts, the total area being about 9310 km^2. There are a total of 62 000 inhabitants in this region, the number of employed persons being 23 000. The main problems of the Ylä-Savo region are unemployment, currently 13 %, and net emigration of about 500 persons per year.

The main sources of livelihood come from services and the food, wood and metal industries. The region has a powerful background based on dairy production with forestry as a supplementary source of income on the farms. The biggest employers are public services with a 30% share, agriculture and forestry with a 19 % share and industry with a 17 % share. The metal industry provides work for 1700 persons. The main companies, PONSSE, producing forest machinery, NORMET, producing mining and forest machinery, and WÄRTSILÄ, producing power plants for bioenergy, are all closely connected to the forest sector. The food stuffs industry provides work for 800 people, the largest companies being VALIO Lapinlahti (producing milk) and the OLVI brewery.

The forest industry provides job for 1080 persons. There are three quite big sawmills located in the Ylä-Savo region, handling a total of nearly a million m^3 of logs. There are also three house factories in Ylä-Savo producing small houses for families and some companies producing furniture, etc. LUNA WOOD is a company using a continuous process to produce heat-modified wood.

Forestry in the Ylä-Savo region takes place in a forested area of about 500 000 hectares. The number of private forest owners is about 10000. The total timber volume is about 55 000 0000 m^3, growth is about 2 700 000 m per year with the allowable cut being 1 900 000 m^3 per year. The volume of timber sales from private forests is about 1 700 000 m^3 per year. Forest owners' associations play a strong role.

The author work has been as a research and innovation manager in Ylä-Savo Region. The affiliation is part of the Ylä-Savo Regional Centre Programme and it is facilitated by Savonia Polytechnic, Kuopio University and Oulu University. The mission of the affiliation is to transfer research knowledge to SMEs, to start R&D projects with SMEs and to enhance the regional innovation system. The main tasks are services for the enterprises, which can include: straight requests from enterprises, e.g. searching for background information concerning a specific idea, for example who are the experts, what is known about it, does it have innovative potential. Services also include preparing product or other development project plans; preparing research projects and providing information about student projects including questions about thesis, the projects themselves, practical training and also educational projects.

Conclusions

Innovation policy has implications at the practical level – those working in the forest sector need a to be able to take full advantage of a learning process, especially from the rural development point of view. The forest sector is focusing on incremental, sustainable innovations – and the need to put more emphasis on radical, disruptive innovations which create growth (Cristensen and Raynor 2003).

The main questions to be resolved are:

- How to identify and select the best ideas for innovations at a given time?
- How to shape the selected ideas into successful new product launches?
- Incentives supporting these processes
- Lack of the information and know-how concerning new markets and opportunities
- Need for information transfer arrangements that allow dialogue and interaction
  - with research, education and training
  - within forestry, intersectoral coordination with timber and paper industry and cross-sectoral relations

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4.3 An Examination of the need for afforestation in Northern Ireland

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Abstract

Northern Ireland is the least forested country in the European Union with only 6% forest cover. Despite having one of the most suitable climates for growing conifers, previous afforestation schemes within the region have been unsuccessful. The main aim of this research is to examine the need for further afforestation programmes in Northern Ireland and to determine the impacts expansion schemes will have on the local community. The work presented describes the current forestry situation in Northern Ireland and discusses the forthcoming independent forest strategy. It also highlights the region's potential with regard to its timber production industry and obtainable woodland cover. In this paper the region's afforestation schemes are examined and the specific reasons for the success and failures are identified. This research provides recommendations for Northern Ireland Forestry and attempts to aid the region in meeting its global commitment of promoting sustainable development.

Keywords: Northern Ireland, afforestation, forest expansion

Introduction

Northern Ireland (NI) is the least wooded country in the European Union and its impact on global forests is quite sizeable and ever increasing. There are presently 83,000 hectares of forest area in NI, which can be divided into three districts, North, East and West (Anon 2004). The region is located in the extreme northwest of Europe and is considered to have one of the most favourable climates for growing conifers within mid-latitude environments. The average growth rate for conifers in Northern Ireland is three times the European average.

Forestry in Northern Ireland has progressed through turbulent times. Since the early 20th century the Forestry Department and the Department of Rural Development have addressed the challenge of restoring and enhancing the forest areas. The forest area now stands at 6%; however the region is considered the least wooded region in the European Union. Significant forest expansion is needed to equal the European average of 36% forest cover. As statistics emerge that NI consumes over five times more wood than is actually produced within the region, forestry policies, legislation, timber production and the corresponding forest industry have come under much needed review.

As forest policy is now an international matter, Northern Ireland has attempted to come in line with international standards by carrying out comprehensive reviews of forest procedures. The entire forestry review has been driven by several key issues. These include:

- How to obtain best value from the Forest Service estate.
- The need to secure a balance of public benefits from forests through environmental improvement, public access and timber production.
- The continuing scarcity of forest in Northern Ireland compared with other countries.

The current review is being carried out with the aim of creating a forestry strategy independent from other countries' direction. An initial consultation document for this was published in June 2002. Prepared by the Department of Agricultural and Rural Development, the aim of the consultation document was to allow key groups within the local forest industry and indeed the general public to voice their opinion on the future of NI forestry. With the final publication of the independent forest strategy approaching, many industry representatives feel the information to be contained within it to be already out of date. It is however important to recognise the step the region is making towards a better future in forestry.

With regard to the timber industry in Northern Ireland, it supports development of the NI economy and therefore remains an important objective of forestry policy. The forest sector has a turnover of approximately £30million, representing 2.5% of the GDP and 5% of employment. The annual revenue generated from timber sales by the Forest Service is reported to be £5.4m. Current concerns about the local timber industry relate mainly to its possible progression whilst ensuring other policy objectives, i.e. environmental and social objectives are met (Anon 2005). In terms of the potential from timber production, it has been estimated that Northern Ireland could produce more volume than is currently being harvested. However, current policy aims to sustain timber production levels and as a result the forest service has negotiated term contracts with main timber customers to produce 400,000 m^3 annually for the period 2004/08 (Anon 2002).

The forests in Northern Ireland also provide unquestionable social benefits. Recent research demonstrated evidence of a strong public interest in substantially increasing the amount of woodland in NI. Each year over 2 million visits are made to local forests, this figure set against the population total of 1.6 million highlights the need for forest areas in the region. The latest figures show that the Forest Service receives annual gate receipts of £0.6m for car parking, caravanning and camping in many of the regions forest areas. Current research carried out by Hutchinson *et* *al.* (2001) established a model for calculating visitors' willingness to pay for access to forests. From this the Forest Service has estimated that an additional value of visits to its forests could total £1m (Anon 2005).

In order to establish if a need for further afforestation exists within Northern Ireland a number of key issues must be examined. These include the previous performance of the regional afforestation schemes and an understanding of the reasons for the successes and failures. The proposed impacts further afforestation schemes may have on the local community must also be assessed in order to identify if further afforestation will benefit the region.

Afforestation in Northern Ireland

At the start of the 20th century woodland covered approximately 1% of the land in Northern Ireland and little of this resembled natural woodland. Research has been undertaken as to why NI has fewer woods than most other regions in Europe. McCracken (1997), Kula (1988), Hall (1995) and O'Carroll (1984) identified many reasons for the shortage of woodland. They include:

- Population growth and the expansion of agriculture
- The use of wood as a fuel, a raw material for industrial expansion and in construction
- The effects of wars and civil unrest
- Environmental constraints, such as available mineral soils, periodic severe storm damage and unreliable natural regeneration have also made a significant contribution to the scarcity of woodland
- The grazing pressure resulting from the extensive livestock rearing that is practised in many parts of NI

These reasons have affected the success of afforestation schemes at different periods. Since the 1950s there has been an active state afforestation programme in place to try and reverse the deforestation trend of the late 1880s. This trail of forest destruction was mainly linked to the impact of the famine of 1845–1849 and the implications of legislation in place at that time. The effects of war and civil unrest meant that little progress was made in the region with regard to forest expansion until the early 1900s. The state became active players in forestry in 1910 when the first state forest was taken over (Kilpatrick 1987).

In terms of afforestation schemes, Northern Ireland has experienced changeable levels of success. The period from 1970–1980 accomplished the first major legislative step in forestry with the publication of a white paper. This step forward however was to be short lived with afforestation progress being hampered whilst the matter of land for forestry was urgently investigated. As a result of the setback, annual planting decreased steadily throughout this period until it reached a mere 1000 hectare mark by 1980 (Kilpatrick 1987).

The period from 1980–1990 practised a much more focused approach to forest expansion. The white paper proposed a target of 120,000 hectares to be achieved by the year 2000. If achieved this would have increased the total percentage of forest cover in Northern Ireland to a total of 9%.This target was never reached; however as a result of satisfactory grants schemes there was a rapid increase in private afforestation during this period.

The period from 1990 to the present day has experienced a mixture of commitments from both the state and private sector. Figure 1 shows the annual planting areas for state and private sectors from 1991 through until 2001/2002. During this period the government's approach to afforestation has altered significantly to encourage afforestation on land where forestry is considered to be the most appropriate long term land use. Afforestation levels have fluctuated greatly on both the state and private side. A recent statement concerning afforestation provides guidance on how to achieve uniformity of approach between public and private sectors.

Currently the government owns and manages 77% of the forest area in Northern Ireland. The remaining 33% of forests are privately owned but to date most are not primarily managed for timber production.

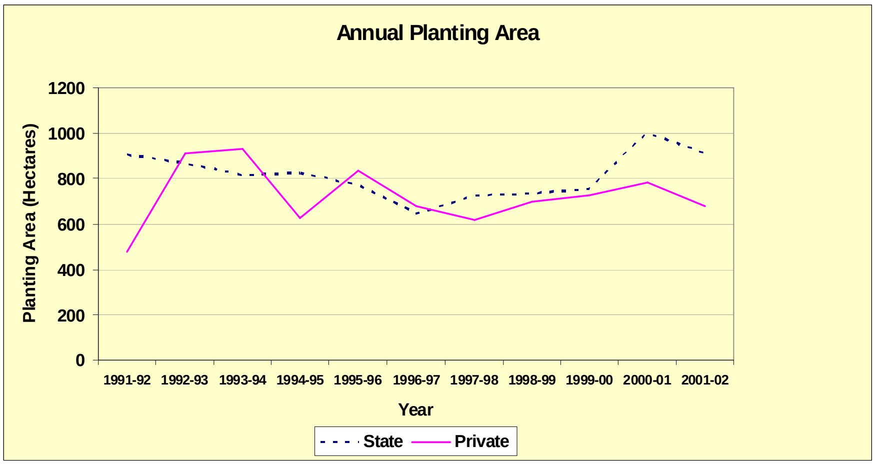

Figure 1. Annual planting areas for state and private sectors

The direction and impact of further afforestation

The lack of forest cover, high consumption rates and international commitments highlight that a need for more forest areas exists. Due to a significant shortage of state land, the future of afforestation in Northern Ireland has become increasingly dependent on the private sector. If this is to be the preferred direction of forest expansion, it is necessary to understand the major challenges facing the private sector. The main weakness primarily concerns the fact that many types of woodland, within private ownership, are of relatively small scale; this is represented in Figure 2 (Anon 2005). Other major barriers affecting the private sector include the availability and attractiveness of grants as well as the longstanding dependence on agricultural industry.

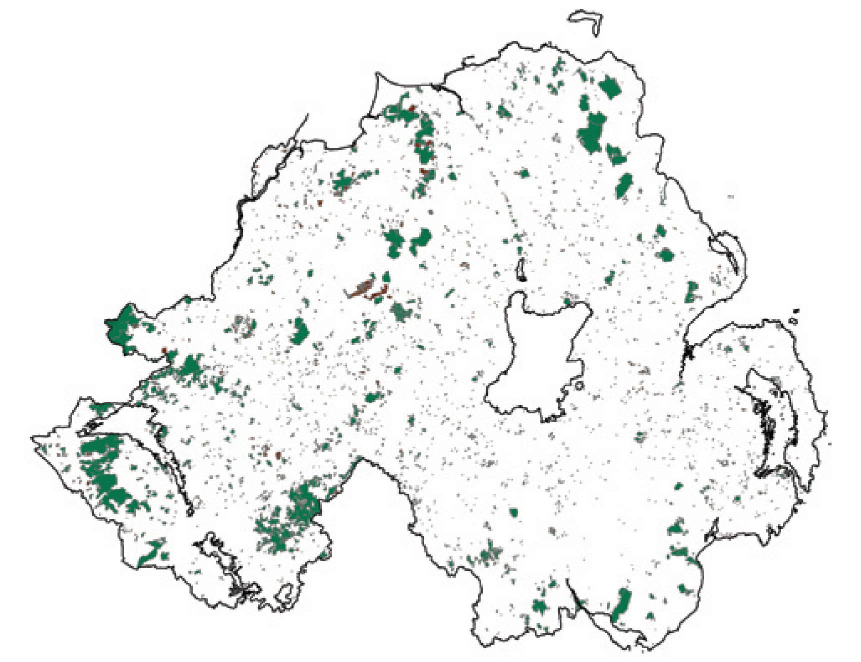

Figure 2. Forest Areas in Northern Ireland

To date private sector participation within forestry has been somewhat limited within Northern Ireland. In order to increase the national forestry estates a suitable strategy must be devised which encourages farmers to use surplus agricultural land for planting. In depth research has been carried out into farm forestry involvement within the region and various recommendations have been suggested to improve the private sector afforestation guides and incentive schemes.

With regard to the impact of further afforestation, the principal impression would be felt on the local landscape and farming community. Research identifies that the process of afforestation can generate many environmental and socio-economic benefits. However, it is important to understand that significant negative impacts can occur if expansion programmes are not managed effectively. Table I summarises the positive and negative possible impacts of additional afforestation on the region.

Table 1. Possible impacts of additional afforestation

Impacts	Benefits	Costs
Social	- Additional areas for recreational use - Positive visual Impact - Formation of positive areas for urban communities - Employment - Revitalise derelict and degraded land	- Negative visual Impact - Possible population displacement - Change on employment income and equity
Environmental	- Reduction of CO_2 emissions - Reduction in soil erosion - Improvements in biodiversity - Better balance of broadleaves and conifers - Diversity of timber type	- Impact on biodiversity - Impact on ancient woodlands
Economic	- Increased timber for local use - Increased timber for export - Further employment - Better economic diversification in rural areas	- Higher monetary incentives required to encourage private sector - Initiation costs

It is clear that it would be difficult if not impossible to introduce further afforestation without creating some forms of negative impact. Procedures and tools such as environmental impact assessments and cost benefit analysis can be used to try and determine if the project is feasible before implementation. The key to successful further afforestation is to assess each project on an individual basis and attempt to balance the predicted benefits and costs.

Conclusion

In light of the evidence shown in Table I and the background information provided on forestry in Northern Ireland, it is evident that a need for further afforestation exists from a number of perspectives. Increased afforestation would appear to provide the region with a vast amount of benefits as well as bringing the region into line with national and international commitments. Recent research by the forest service has identified the main benefits of expanding the forest area to be in terms of landscape and environmental improvements. It has also been suggested that once forests have been created, there is likely to be significant economic activity in processing the timber. It is unlikely that the region will become a main player within European major timber markets. However, there is no doubt that if managed effectively the timber production industry can flourish from further afforestation (Anon 2005).

In terms of private sector participation several key groups strongly believe that private owners will not invest in forests to exclusively produce timber. Primary findings however from a pilot study carried out by the author suggest that local farmers hold a keen interest in the forestry process. It is felt that the continual separation between the agricultural industry and the forest industry has led to complexity within the forestry process. It is essential that such an issue is addressed if private sector participation is to increase. Other recommendations regarding the improvement of the private sector include the revision of grant schemes and the review of farm forestry processes. Improved mechanisms of recording timber production within the private sector are also essential.

Through the evaluation of current research the author has identified several important recommendations to improve Northern Ireland forestry, some of which have been mentioned above. Areas also requiring attention include the need for more ongoing research within the forestry sector and improvements on forestry education and training to meet the needs of the industry more effectively. The challenge for Northern Ireland remains to develop a comprehensive afforestation strategy that can provide recognised benefits for the local community and balance all environmental, social and economic objectives. Identifying workable strategies from other countries may help to create a sustainable successful policy. The author's further research shall identify successful strategic elements from other European countries and attempt to evaluate the possible benefits for Northern Ireland if implemented.

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4.4 Woodlands for shelter in the Westfjords (Skjólskógar á Vestfjördum)

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Introduction

Woodlands for Shelter (Skjólskógar á Vestfjördum) was started in the year 2000 and is one of five regional afforestation programmes in Iceland. The project covers the NW area of Iceland, the Westfjords peninsula (Figure 1).

The stated aim of the project is to grow forests and shelterwoods on 5% of the area below 400 m.a.s.l.

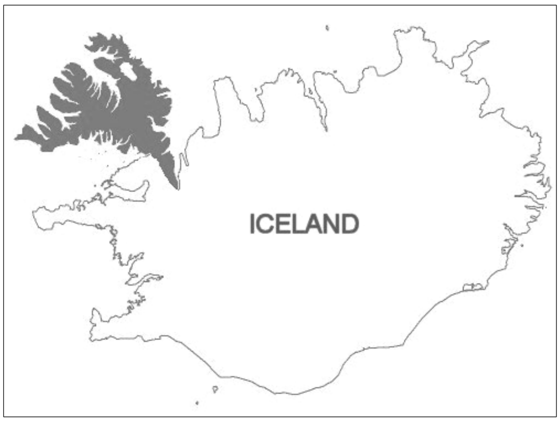

Figure 1. The project "Woodlands for Shelter" covers the NW area of Iceland.

In Iceland, like the rest of Europe, forestry was earlier only seen as profitable as a source of timber, and timber production can hardly be seen as a profitable enterprise as such in the Westfjords. The concept of multipurpose forestry opened new possibilities for forestry in the Westfjords, as in other marginal areas.

The Westfjords has an area of 9,044 km^3 and is a mountainous area with deep fjords and a long coastline. But the land below 400 m.a.s.l. is only 5,673 km^3 in area. Forest cover accounts for about 4% of the lowlands, mainly birch forests and scrub, but there are also some small conifer plantations dating from the 1950´s. They were planted by numerous forestry associations in several locations in the Westfjords. In these small forests we find history and experience that help guide today's afforestation.

The project

The project Woodlands for Shelter is a government funded afforestation program set for 40 years. Its purpose is to grow shelterbelts and forests on at least 5% of the land under 400 m a.s.l. and to manage the natural forests in the area. The project works with landowners in the Westfjords. Landowners must apply to participate in the project and the minimum area of land to be afforested is 10 ha on each farm. According to the nature conservation law an area that goes beyond the threshold of 200 ha could be required to undergo an environmental impact assessment.

When the landowner has applied for his land and manifested his land ownership, his land is surveyed and the following ascertained: former and future land use, soil type, soil- depth and fertility, vegetation, main wind direction, slope steepness and slope direction. An afforestation plan is made, based on land quality and the landowner's intentions. The plan includes protection from grazing, cultivation, species composition and density. The plan's duration is 10 years; after 3–5 years each farm is reassessed, tree growth measured and the plan reviewed.

The main species planted by the project are: Birch (*Betula pubescens*), Sitka spruce (*Picea sitchensis*), lutzii spruce (*Picea lutzii*), Russian larch (*Larix sucaczewii*), Lodgepole pine (*Pinus contorta*), willows (*Salix* sp.) and black cottonwood (*Populus trichocarpa*).

A part of very plan consists of three site maps in the scale 1:5000. The maps are made of a coloured upright aerial photograph. One shows the compartments according to site conditions, roads, paths, lakes, streams, conservation areas such as ruins, and wetlands. The second is a cultivation map and the third shows species composition in each plot and level curves.

The project hopes to have positive effects on farming conditions in this harsh area, including environmental factors such as: increased growing season temperature on cultivated land, increased grazing capacity by woodland pastures, decreased impact of funnelling winds, control of snow accumulation around buildings and on roads, and the diversification of farming by forest operations (Figure 2). The program will hopefully slow down the depopulation of the area and encourage investment in a new resource that will benefit both the economy and the society.

Farm forestry

Part of the afforestation project is to study farming practice, number of livestock, grazing management, the growing of crops and the state of the vegetation on the farmland.

Most farmers in the Westfjords are sheep farmers. In traditional sheep farming, sheep are kept indoors about 6 months a year and early spring grazing is usually in the hayfields. During summer and autumn the sheep roam free on hillsides and highlands. In the autumn the sheep are gathered and most of the lambs are slaughtered in September and October. With new customer demands of fresh meat supply and quality management in sheep farming (lamb meat production) these traditional methods are slowly changing. Fresh meat is becoming available for a longer period and the obligation to use the wilderness in a sustainable way demands increased grazing control which in turn calls for improved land management.

Figure 2. The farm forestry in the Westfjords consists of shelterbelt systems on hayfields and arable land, grazing pastures and woodlands

A land management scheme is developed to meet these demands. The constant factors of these schemes are fenced areas for cultivation of pastures from degraded areas, growing of woodland pastures and exclusion of sheep from hayfields.

Farm forestry in the area consists of shelterbelt systems on hayfields and arable land, grazing pastures and woodlands (Figure 2). Shelterbelt systems are grown mainly on cultivated land and around houses. Their purpose is to protect cultivation and buildings from winter gales and chilling summer breezes. The effect is to lower the cost of house heating and increase the growing season temperature with a resulting increase in the productivity of livestock and vegetation and which could make the growing of cereals for fodder possible.

The beds are ploughed with fertilizer, mostly manure, then harrowed and a plastic sheet laid on top to restrain weeds and increase the growth of the shelterbelt. Willow cuttings are mostly used in these belts. Most shelterbelts have two to three rows but wider belts, up to five rows, form the borders of the system. These wider belts are designed as snow traps, a necessity in the prevailing conditions.

Shelter woods are small woods with a mixture of trees and density where livestock seek shelter in bad weather and for short-term grazing. Grazing mostly refers to ewes with lambs in the spring and the summer grazing of cattle. These woodlands are often connected with shelterbelt systems and are mainly grown with broadleaves.

The grazing woodlands are a mixture of 60–70 % broadleaves and 30–40% conifers. The density is on average 1000 plants ha^{-1} planted at 3x3m interval with denser groves. The combination of dense groves and open areas increases the diversity of the undergrowth and prevents wind streams in the wood.

Native woodlands

Planting of new native birch (*Betula pubescens*) forests with local provenances is a large part of the project (Figure 3). Landowners grow them for their aesthetic value and as an attraction for tourism. There is increasing demand for summerhouse plots in birch forests and growing such forests can help protect the ancient woodlands from development.

Figure 3. Native birch (Betula pubescens) woodland.

The pioneering attributes of birch will also be of use in land reclamation and protection forests. Experiments and studies have been launched to monitor the effect of grazing, thinning, felling and other factors on natural birch woods and associated species, i.e. rowan (*Sorbus aucuparia*). A total of 56% of the land area in the lowlands has been classified as having *substantial* to *a great deal of* active soil erosion. Half of this is related to barren steep mountainsides and the other half is around farmsteads, mostly related to heavy grazing. Protection forestry is therefore on the one hand general soil and vegetation reclamation on lowland and on the other hand the developments of methods in which deep-rooted arborecious species are grown on steep mountainsides. The resulting snow cover will decrease frost heaving and increase protective undergrowth.

Shelter woods

The Westfjords have magnificent landscapes, where high mountains and deep fjords produce strong funnelling winds which are very unstable. Computer simulations that compare barren landscape with the higher surface resistance of forested land indicate that these unstable winds can be reduced substantially (Figure 4.)

The design of woodlands in narrow valleys and steep slopes to maximize surface friction is an ongoing process, relating to location, architecture and species composition.

Figure 4. Woodland gives higher surface resistance to winds.

The designing of shelter woods is based on species diversity and landscape. Plant density is on average 1600 plants ha^{-1}, the density differing from open areas to dense stands. Effort is made to have the forests as diverse as possible and preserve the natural essence of the landscape. Shelter woods also play a role in outdoor activity; hiking, camping and enjoying nature.

Timber production

Although the Westfjords have never been considered a profitable timber production area, recent studies on small forests planted in the 1950´s and 60´s have shown annual volume growth in Sitka and lutzii spruce up to $11m^3\ ha^{-1}\ yr^{-1}$ (Figure 5.)

In fertile areas such as former hayfields, multipurpose forests are planted. Their species composition is aimed mainly at timber production. The minimum size for these areas is 20 ha. Shelterbelts and shrubs are planted to increase temperature, on average with a 4.5m interval and closer on the windward side. About 2500 plants are planted per ha. All plants get fertilizer when planted. This type of forestry has been on the increase in the last few years because of depopulation of the rural areas and difficulties in farming. More and more fertile land has become available for forestry and the time frame for protection and soil reclamation forestry has also increased due to less grazing pressure.

Figure 5. Potential timber forest in Westfjords.

4.5 Guide to good afforestation practice in Iceland – An interdisciplinary approach

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Introduction

Afforestation has been increasing in Iceland in recent decades. Forestry is now becoming a common land-use alternative, both for small- and large-scale landholders. There is a great interest in increasing the forest and woodland cover for multiple objectives, but the current cover is only approximately 1.3% of the country, which is the lowest cover in Europe. The 1100 years of settlement have resulted in a loss of around 95% of the original woodland cover.

Afforestation implies changes on various levels. These changes can affect the natural environment, cultural and archaeological heritage, and landscape in general. Consequently, a need has emerged for guidelines aimed at the various stakeholders involved in the afforestation work, providing guidance for best practice.

To provide such guidelines, the Icelandic Forestry Association initiated the formation of an interdisciplinary working group in 2002. The group was composed of key stakeholders from a range of governmental and non-governmental organizations with a vested interest in the afforestation work.

Web-based information material

The group has produced web-based material, now published at the domain www.skog.is/leidbeiningar.htm, called “Guide to good afforestation practice in Iceland”. People engaged in afforestation can easily access the guidelines in order to improve their work. The idea behind the web-based publication format was to provide easy on-line, on-demand access for the various stakeholders country-wide and at the same time facilitate updating the material.

The web-based guidelines use an easy-to-follow, red-yellow-green approach to guide the reader. Although it is a web-based publication, the material is divided into three main sections, addressing firstly land selection criteria, secondly definitions of afforestation objectives, and thirdly general guidance for good practice.

Land selection categories

This section deals with land selection, providing three main categories. Firstly, areas where *afforestation is generally not recommended* are defined according to various constraints (red colour). Those constraints are mainly related to nature conservation and biodiversity, archaeology, drinking water quality and regional/local land use planning. This section is strongly nested in various laws and regulations as the web provides links to all relevant acts and bylaws.

If the respective afforestation site does not fall under the first category, the reader moves ahead to the second category, This category deals with areas *where afforestation is conditional* (yellow colour). These conditions can include environmental impact assessment requirements, water catchment areas, biodiversity and nature conservation, and archaeological sites.

If the proposed afforestation area does not fall under these two categories, the reader can proceed to the next two sections providing guidance about afforestation objectives, planning and best working practices (green colour).

Afforestation objectives

This section guides the practitioner in identifying the objectives of the afforestation work that subsequently affect the applied practice. The various afforestation objectives offered are, in alphabetical order: land reclamation forestry, native woodlands recovery, recreation and nature tourism, shelterbelts, commercial production and urban forestry. Furthermore, as these objectives evolve and combine with others, afforestation with a multiple-use objective is common in the Icelandic context.

Good forestry practice

The last section of the guidelines deals with good forestry practice in general, following adoption of the land selection categories and clarification of objectives. This section has various components, ranging from preparatory issues like forest management plans and landscape issues to more direct on-the-ground practical issues like site preparations, fencing, road construction and fertilizer applications.

Concluding remarks

Forests are gradually emerging again as a significant component of the Icelandic landscape. Given the increase in new plantings, there has been a great need for the provision of good practice guidelines for the various stakeholders involved. The guidelines described in this paper are the first attempt to provide such information.

The interdisciplinary approach selected has greatly facilitated the reception and acceptance of the guidelines. The fact that the guidelines are not solely a product of foresters adds significantly to their legitimacy in the eyes of other stakeholders.

For the various stakeholders, both forest farmers, forest societies and others, following these guidelines is done on a voluntary basis. There is no enforcement or set of standards that must be adhered to for afforestation. Therefore the main challenge is to educate the various forest practitioners about the guidelines and to encourage adherence to them.

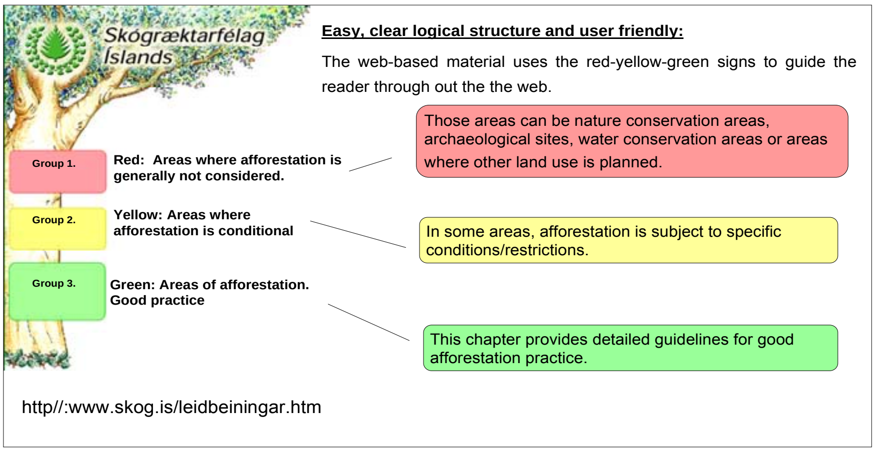

Figure 1. The structure of the web is easy to follow.

4.6 Silvicultural methods for increasing sustainability of afforestation on post – agricultural lands in Poland

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Abstract

Afforestation on the abandoned agricultural lands in Poland covers more than one million hectares. In the past, farmlands were regularly afforested with Scots pine, often guided by communist system ideology (quick and high timber production, simple afforestation method). Due to quick afforestation of land, forest stands were unstable and very often prone to various kinds of diseases. The paper briefly describes the history of Polish afforestation and provides information about stand age structure. Ecological threats causing the most serious damage to restocked areas are characterised.

Silvicultural methods which are to serve formation of sustainable and highly biologically diversified forest ecosystems are also presented. Taking into consideration economical, protective and social functions of forest stands much attention is being paid to the differentiation of silvicultural management depending on management goals. In this paper the previously established afforestation experiments are used as a case study. The objective of these studies is to evaluate the growth dynamic of the young generation of Scots pine stands to which various thinning methods have been applied.

Keywords: Afforestation, Scots pine, former agricultural land, silviculture, assessment

Introduction

The reforestation of abandoned farmlands in Poland had begun at the turn of the 19th and 20th century; however, reforestation efforts dropped during the inter-war period. Nearly 300 thousand hectares of stands planted before the outbreak of World War II have been preserved until today. The afforestation process in post-war Poland is illustrated in Figure 1. The greatest scope of afforestation took place between 1949 and 1967, amounting to 45 thousand hectares of land per year. In 1968–1980 only 18–19 thousand hectares were afforested, whilst in 1981–1991 this figure was 5–8 thousand hectares per year. After signing loan agreements with the International Bank for Reconstruction and Development and the European Investment Bank in 1993, a marked increase in afforestation was recorded. In 1947–2003 afforestation covered 1387 thousand hectares of post-agricultural lands and wastelands, including 792 thousand hectares of state-owned and 595 thousand hectares of non-state owned lands.

In June 1995 the Polish government adopted the National Programme for the Augmentation of Poland's Forest Cover for 1995–2020 in which about 600 thousand hectares were to be afforested.

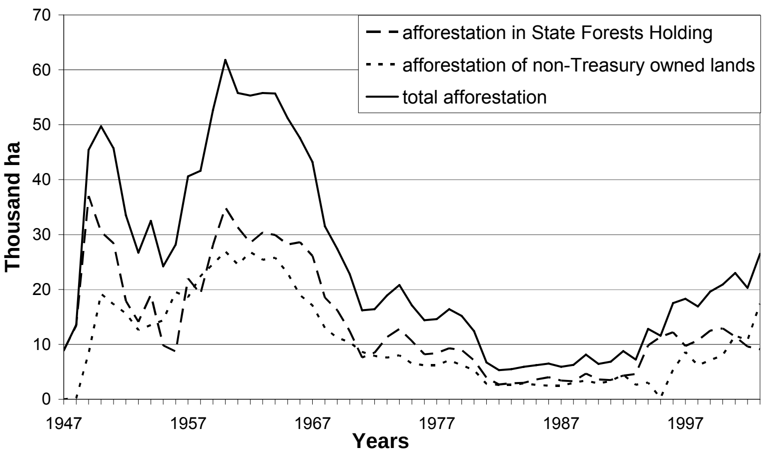

Figure 1. Afforestation in Poland in the period 1947–2003

Since 2003, afforestation costs have been covered by the State budget on the strength of the Act on afforestation. With Poland's accession to the European Union afforestation has been subsidised within the framework of the Sectoral Operational Programme "Restructuralisation and Modernisation of the Food Sector and Development of Rural Areas" and the "Rural Development Plan".

Silvicultural management principles for stand growing on former agricultural land

Lacking proper soil analyses, these lands in the past were generally afforested with Scots pine, often guided by communist system ideology: quick and high timber production and simple afforestation methods. In this way the lands were quickly afforested, yet the question of correct forest-forming processes and sustainability of newly established forests have been left for the following generations to be solved. This problem has become very serious. The difficulties are due not only to the unsuitable species composition of young stands but also to technological mistakes made during afforestation campaigns, in particular to: unsuitable soil preparation resulting from an incorrect development of pine root system and susceptibility to diseases, incorrect planting during social labour campaigns involving school children or army, colonisation of uncultivated soils by grubs and lack of grub control treatments, excessive planting density (17–21 thousand pine seedlings per ha), and insufficient frequency of tending and protective treatments in plantations and young stands.

Currently, the most important issues concerning stands growing on former agricultural lands are:

a) Occurrence and spread of root-rot (Fomes annosus = Heterobasidion annosum) and Armillaria species. Today the infectious diseases of high intensity are recorded on nearly 180 thousand hectares. The infested stands require quick conversion and persistent control of these pathogens.
b) Occurrence of other fungal epiphitoses (Gremmeniella abietina and Cenangium ferruginosum) attacking mainly 10–40-year-old pine stands. The disease forced sanitary felling on about 13 thousand hectares. Disease-causing pathogenic fungi are usually accompanied by insect pests.
c) Damage caused by snow and wind to the untended or poorly tended stands planted on former agricultural land.

Silvicultural management on post-agricultural lands in Poland focuses on:

a) Suitable choice of species depending on climatic and habitat conditions.

Prior to plantation on post-agricultural lands soil analyses are necessary to choose the most desirable species and attain a diversified stand composition.

Land designated for afforestation is subjected to grub control using chemical (insecticides) and mechanical (ploughing) or biological (growing buckwheat) methods. Ploughing with churning up the soil with a scarifier (at a depth of up to 50 cm) is applied in autumn prior to planting. The main species in the composition of afforestations growing in fresh coniferous forest habitats are mainly Scots pine (60–80%) and birch, larch, spruce, sessile oak, European beech and other broadleaves. In more fertile coniferous forest habitats the share of pine drops to 30–50%, while a marked increase in the share of broadleaved species and fir is noted in the upland and mountain regions. Broadleaves are the prevailing species in stand composition in fresh mixed broadleaved forest habitats with the share of pine constituting maximally 40%, whilst on more fertile sites pine is rarely planted.

Approximate number of seedlings per hectare is given in Table 1.

Table 1. Approximate number of seedlings per hectare (these figures can additionally be reduced by as much as 30%)

Tree species	Number of seedlings in thousands per ha
Pine	8–10
Spruce	3–5
Fir	6–8
Larch	1.5–2
Douglas fir	3–4
Oak	6–10
Beech	6–8
Other broadleaves	4–6

In the case of containerised seedlings these figures can be reduced by as much as 40%.

Seedlings used for afforestations are: 1- and 2-year-old pine, 2-year-old larch, 2- and 3-year-old fir, spruce and broadleaves.

The most common species used in the first generation stands established on more fertile sites are: pine, birch, larch, spruce, black alder and aspen. In this case the initial density for pine is 5-7 thousand seedlings per hectare; larch 1–1.7 thousand seedlings per hectare; and for broadleaved species 2–3 thousand seedlings per hectare. After the canopy closure, pine thickets are thinned to reduce the number of trees to 1–3 thousand seedlings per hectare and any gaps are restocked with admixture species. The expected effects of these operations are multi-species, stable, biologically diverse and near-natural forest ecosystems.

b) Conversion of damaged stands

Diseased stands are designated for conversion as the first step. The conversion includes restocking of gaps and clearings, underplanting and introduction of understorey vegetation using broadleaved species resistant to root diseases. When the total gap area exceeds 50% of the stand area a complete conversion of the stand is applied, including restocking of an open area.

c) Tending treatments

Tending treatments applied to stands at various stages of their development are oriented towards shaping species composition (including valuable natural regeneration) and resistance of stands to the biotic and abiotic factors (including maintaining good sanitary conditions), as well as increasing their silvicultural quality. In the managed stands owned by the State Treasury the selective cutting system is the obligatory method of forest management. At the stage of early thinning the method depends on selecting and promoting the appropriate number of trees from the upper canopy showing the highest silvicultural value and increment, and promoting trees (if there are such) providing shelter to crop trees (the whole forming so-called biogroups). In pine stands of the highest quality class (bonitet) it is recommended that the first thinning should be started when the average stand height is 10 m, in the stands of bonitet class II and III –

8 m, and in the stands of bonitet classes IV and V – 6–7 m. The treatments are repeated every 5–7 years, and in older stands, every 8–10 years (the treatment is applied more often to fertile sites).

A major goal of selection in the stands of poor health condition (frequently these are stands established on post-agricultural lands) is the protection of the most vital trees. In the stands attacked by fungal diseases the improvement fellings play the role of sanitary fellings aimed at impeding the disease development process.

The intensity of a single thinning treatment in healthy pine stands with the composition of species adjusted to the capabilities of the habitat should not exceed 10–20% of the stand volume. However in the stands of poor sanitary condition and those requiring changes in species composition heavier thinning should take place (15–30% of the stand volume) combined with underplanting or refilling of gaps with other species.

Thinning studies at the Silviculture Department of the Forest Research Institute

One of the research projects carried out by the Silviculture Department concerns the choice of the selection thinning method applied to healthy pine stands. The objective of the experiment is to compare the effects of the traditional method of selective thinning and some of its currently used thinning versions on the growth of a pine stand in age class II, its structure and biometric parameters used to determine its stability under the impact of adverse factors. Because the effect of the initial density of a stand on its growth is as important as the felling itself (Petersson 1993) the methodological postulate that thinning experiments should be carried out in the stands established from planting under the known spacing regime seems justified. In the case of stands varying in initial density it is possible to research the effect of both factors (density and thinning) on the growth, stability and productivity of a stand.

Methods

Since 1999, a new thinning experiment has been continuing on four permanent plots established in the Silviculture Department, Forest Research Institute. These plots were set in a randomised block design in 1965–1966 as part of the framework of the research programme concerning the effect of initial density on the growth of pine stands.

The initial spacing /density used in the experiment were:

A – square spacing 0.80 m / 15625 seedlings per/ha,
B – square spacing 1.00 m / 10000 seedlings per/ha,
C – square spacing 1.20 m / 6944 seedlings per/ha,
D – triangle spacing 1.00 m / 11547 seedlings per/ha,
E – triangular spacing 1.20 m / 8019 seedlings per/ha,
F – rectangular spacing 0.55 x 1.20 m / 15152 seedlings per/ha,
G – rectangular spacing 0.80 x 1.20 m / 10417 seedlings per/ha.

The plot in the Parciaki Forest District was established in 1966 on a fresh coniferous forest site, site class I, on former agricultural land. Prior to the thinning experiment the stand had not been tended. The experiment consisted of three replications:

- Traditional thinning (variants B and E) – crop trees were selected, totalling as many as 500 trees per hectare. Among adverse trees no more than one tree was removed from the overstorey.
- Group thinning (variants A and D) – as many crop trees were selected as in the traditional thinning, increased by the number of trees growing in close proximity (within one “biogroup”) that were also regarded as crop trees.
- Heavy thinning (variants C and F) – crop trees were selected, totalling as many as 350 trees per hectare. All competitors growing in the close neighbourhood whose crowns had contact with crop trees were removed.
- Variant G (rectangular spacing 1.2 x 0.8 m) was treated as a control (not thinned).

The criteria adopted in selecting crop trees were based on stem diameter (index WP3) and crown quality. Index WP3 denotes the ratio between the dbh of a given tree and dbh of the 100 thickest trees per hectare and is used for modelling individual tree height (Hynynen 1995). The studies carried out in the Silviculture Department, Forest Research Institute (Zachara 1999) demonstrated that the WP3 index describes the competing position of a tree in the environment much better than the individual dbh to average stand dbh ratio. The index value adopted for the dbh lower limit is 0.75.

The entry with thinning was designated in 2000.

Preliminary results

The experiment was established when the discussed stand reached 35 years of age, which is slightly later than the time when thinning should be commenced under average conditions. The experiment provided an opportunity to study the response of a previously unthinned stand to thinning operations. In the pine stand of age class IIb the impact of the initial density (in the examined range from 0.8 x 0.8 to 1.2 X 1.2) on the basal area was not significant. However, it had an effect on the average stand dbh and tree slenderness (Figure 2a).

The initial density also affected the quality and biometric parameters of the selected crop trees. The crop trees selected were in a stand established by planting in a narrow initial spacing (about 15 thousand seedlings/ha) and not subjected to intensive tending treatments reveal excessive slenderness (Figure 2b).

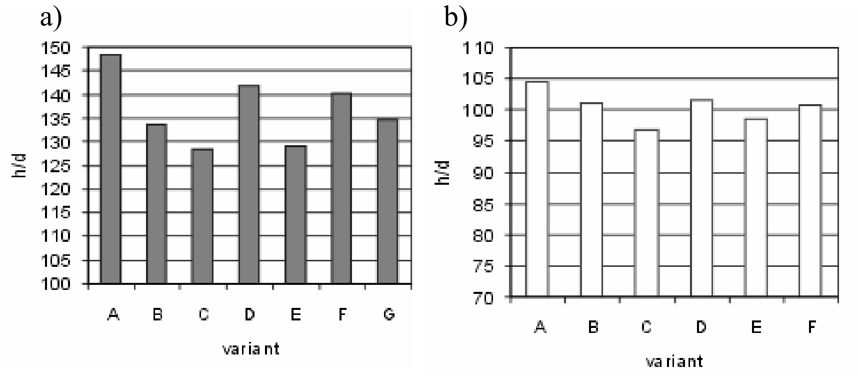

Fig 2. a) Tree slenderness in various stand density variants (Parciaki)
b) Crop tree slenderness in various stand density variants (Parciaki)

In untended stands the use of fellings that do not disturb tree groups in the upper canopy are least exposed to risk (Zachara 1999). Distances between crop trees should not be a decisive criterion of their selection.

Heavy final crop-tree oriented thinning can be used on a limited scale in the stands with wide initial spacing or in intensively tended stands in the thicket phase and in mixed stands that are partly pine. Heavy thinning used in the studies can be compared with the heavy thinning method applied to pine stands in the Czech Republic described by Pařez (1980). In the 15-year-studies he demonstrated a negative effect of such heavy thinning expressed in permanent decline in stand volume and share in dominant tree class.

The preliminary conclusions concerning thinning require confirmation in successive measurement cycles on the experimental plots.

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4.7 Afforestation in Norway – effects on wood resources, forest yield and local economy

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Introduction

Most countries in Europe have experienced loss of natural forest cover as land has been cleared for farming and other uses. Lack of timber and firewood resources over the last 350 years has been a driving force behind most afforestation work. This paper discusses the history and some major trends and drivers in the afforestation process in Western Norway.

The history of the countryside

To understand the impact of man on the environment is important if we want to understand how woodlands have evolved. Density of population, technological capabilities, the economic setting for trade and the socio-political questions (property forms, etc.) are important factors in most cultures that utilize forests (Kardell 1988). The immense contrasts in the geography of Norway have also been reflected in the regional patterns of forest uses, for instance the difference between the inland valleys and the coastal plains (Robak 1960). Especially in the coastal districts of Norway, where a high number of farms were established in AD 500 –1500, most woods were eradicated by clearing and fires and replaced with heathland, fields and pastures. However, this man-made conversion was not a simple process of clearance by axes but took place step by step and with considerable local variation up to the 19th century (Kaland 1986). The sparse records of the Middle Ages tell the story that wood for houses and a variety of products had to be transported a long distance by boat. Wooden products (house timber, tar, boats, etc.) were even exported to Iceland, Greenland, Shetland and the Faeroe Islands (i.e. Fryjordet 1992). Later on, when water-driven sawmills became available, a technology that began about 1550, wood was more and more an important commercial trade product and exported to the overseas countries of the UK, Scotland, Ireland and The Netherlands (i.e Tveite 1961, Frivold 1999). However, in W Norway most of the possibility of export strongly declined due to lack of timber resources around 1750.

Throughout history we can identify some major phases in the utilization of woodlands in West Norway, the islands and coastal districts of Central Norway and in parts of North Norway:

- Local exploitation of woods (settlement period), BC 2000 – AD 1550
- Period of great exploitation (sawmill boom period), 1550–1850
- Regional deficit of wood resources, industrialization period, 1850–1950
- Afforestation period, 1950–1985
- Consolidation period, 1985–2005

The same phases could also be identified in other cultural settings in most corners of the world in historical times.

The Norwegian afforestation program

Several countries have embarked on vigorous afforestation or reforestation programs over the last 60 years, by applying different principles. The pertinence of separate property characteristics in Western Norway and the strong cultural identity tied to property rights seem to have played an important role in how afforestation work was organized here (Sevatdal 1971). In the 1920s the Forest Director established a financial fund for municipalities to buy larger areas for afforestation, and in a brochure the good experiences from the early conifer plantations in W Norway were summarized (Skogdirektøren 1921). Several foresters suggested a mixed governmental involvement in the afforestation process by also stimulating private ownership (i.e. Thorsen 1906, Vonen 1925). The first steps towards a national afforestation program were taken in the late1930s when the Forest Director (Skogdirektøren 1937) and a committee of the Norwegian Forest Society (Utmarkskomiteen 1939) evaluated the critical forest situation and examined the possibilities for increasing forest investment in the coastal regions. However, World War 2 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 new wood-based industry (Smitt 1946a). The first really large step was made in 1951 by the White Paper "Innstilling fra Skogkommisjonen[1]" (Skogdirektøren 1951–54), the basic ideas of which were adopted by the Parliament in 1953–54. The major conclusions from this work were:

- In the afforestation areas[2], each municipality was responsible in setting up their own reforestation plans and programs for tree planting and setting priorities. The government was willing to subsidize up to 50% of the cost of establishing new plantations.

[1] This work was a follow-up on the report initiated by the Ministry of Agriculture: "Skogreisingen i kystdistriktene", published in 1949. 67 p + app.

[2] The first plans included the counties: parts of Vest-Agder, Rogaland, Hordaland, Sogn og Fjordane and Møre og Romsdal. From the mid 1950s the coastal districts in Sør-Trøndelag and Nord-Trøndelag, Nordland, Troms and Finnmark County were included.

Additionally, 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).

- Within a period of sixty years the plan was to cultivate 325,000 hectares of land in W Norway and 100,000 ha in N 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 was estimated to reach about 3.7 mill m3 in W Norway and about 1.0 mill m3 in N Norway.

Large-scale afforestation in W Norway began in the late 1950s and early 1960s. The recommendations about tree species and provenances, cultivation methods and management relied on the results from forest research (Skogdirektøren 1951, Heiberg 1957, Bergan 1971, Børtnes 1971). Projects were designed both at governmental and local levels. The Norwegian Forest Society and the Forest County societies were designated to undertake parts of the program, 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 regeneration of broadleaves and Scots pine in the afforestation areas has called for a focus.

Additionally, the forest policy ambitions to enlarge the forested areas and accumulate more timber resources were gradually reduced in the 1980s and 1990s (White Papers; Skogdirektøren 1989, Skogdirektøren 1999).

The effect on growth and yield by changing tree species

From the first plantings and experiences in the afforestation areas 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 (i.e. Smitt 1946, Bauger 1962, Braastad 1966, Braastad 1968, Bauger 1970).

Most Norwegian studies concerning effects of changing tree species in reforestation areas have been conducted in neighbour stands offering equal growth conditions (i.e. Øyen & Tveite 1998). The results from these studies (Table 1) contrast the results from mixed stands in SE Norway and Sweden (i.e. Braastad 1983, Leijon 1979), 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 (c. 250,000 ha), about 45,000 ha Sitka spruce (including a minor part in lutz spruce), and the rest consists of other species such as logdepole pine, Scots pine, mountain pines, larches, Douglas fir, silver fir and other firs, red cedar, western hemlock and others.

Table 1. Effect on tree species conversion on site index and yield over one rotation in Western Norway. Only a few of the most common tree species conversions are shown.

Conversion	Gain in site index (H40 in m)	Gain in yield (m^3/ha/yr)
DB → NS	7–9	6–8
SP → NS	6–8	4–6
NS → SS	3–4	3–4
DB → SP	0	0
DB → SS	8–10	7–9
SP → SS	6–8	6–7
SP → JL	6–8	4–6
DB → EL	6–8	4–6
GA → NS	7–9	6–8

DB=downy birch, NS=Norway spruce, SP=Scots pine, SS=Sitka spruce, JL=Japanese larch, EL=European or Siberian larch, GA=Grey alder. The figures are based on Øyen and Tveite (1998) and other studies/data from Skogforsk.

Extent and constitution of forested land

Afforestation in Norway involves either:

a) Replacement of spontaneous pine with spruce (Norway spruce, some Sitka spruce).
b) Broadleaved forest replaced by coniferous forest (mostly Norway spruce).
c) Planting or sowing on bare land, scrubland and boggy land (mostly Scots pine, mountain pine, Sitka spruce).

Category c) covers about 25 per cent of the plantation areas; most activities have been directed towards former pastures on high and medium site indices with a certain former tree cover (Skogdirektøren 1995). Up to 2005 the cultivated area of spruce plantations in Western Norway was about 165,000 hectares (200,000 ha if Vest-Agder County in the southernmost Norway is included) and about 110,000 ha in Northern Norway (Table 3). The productive forest area has increased by 0.66 mill ha over the last seventy years, not only by afforestation, but also due to reduced grazing and natural regeneration of former fields, heathland and pastures (Table 2). We expect a further increase in forested land in the ensuing decades due to the scaling down of farmland use (Figure 1).

Table. 2 Forest resources in Western Norway (incl. Rogaland, Hordaland, Sogn og Fjordane, Møre og Romsdal) and Northern Norway (incl. Nordland, Troms and Finnmark)..

1930s	Western Norway	Northern Norway
Land area	5.84 mill ha	11.30 mill ha
Productive forest land	0.52 mill ha	0.85 mill ha
VGS, deciduous forest	9.5 mill m^3	18 mill m^3
VGS, pine forest	11.4 mill m^3	4 mill m^3
VGS, spruce forest	0.2 mill m^3	6 mill m^3
AI, deciduous forest	0.33 mill m^3	0.42 mill m^3
AI, pine forest	0.39 mill m^3	0.06 mill m^3
AI, spruce forest	0.01 mill m^3	0.21 mill m^3

VGS=Volume growing stock under bark, AI=annual increment under bark. Figures based on Norwegian Forest and Land inventory and Statistics Norway (SSB)

Table. 3. Forest resources in Western Norway (incl. Rogaland, Hordaland, Sogn og Fjordane, Møre og Romsdal) and Northern Norway (incl. Nordland, Troms and Finnmark).

1990s	Western Norway	Northern Norway
Land area	5.84 mill ha	11.30 mill ha
Productive forest land	0.82 mill ha	1.21 mill ha
VGS, deciduous forest	24.9 mill m^3	31.7 mill m^3
VGS, pine forest	30.5 mill m^3	6.2 mill m^3
VGS, spruce forest	17.7 mill m^3	9.5 mill m^3
AI, deciduous forest	0.8 mill m^3	0.9 mill m^3
AI, pine forest	0.8 mill m^3	0.2 mill m^3
AI, spruce forest	1.3 mill m^3	0.4 mill m^3

VGS=Volume growing stock under bark, AI=annual increment under bark. Figures are based on Norwegian Forest and Land inventory and Statistics Norway (SSB).

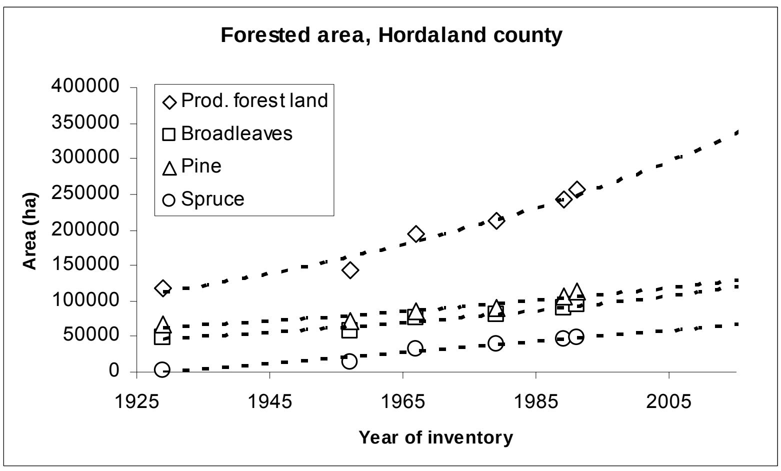

Figure 1. Inventory data (Norwegian Forest and Land Inventory and Statistics Norway) for Hordaland County, W. Norway. The data have been extrapolated up to 2015.

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 spontaneous Scots pine forests in W Norway have an annual production of about 0.8 mill m^3 over bark (i.e. 2.5 m^3/ha) whereas the 165,000 ha of spruce plantations have an annual yield of about 1.3 mill m^3 or 7.9 m^3/ha.

In the work of the Forestry Commission (Skogkommisjonen 1951–54) the predicted yield figure of the spruce plantations was 5 m^3/ha/yr. With a spruce plantation area of 275,000 ha, this would imply a future potential annual yield of about 1.38 mill m^3. However, in the yield tables for Norway spruce in W Norway (Brantseg 1951) the production has varied from 6.1 to 14.7 m^3/ha/yr, so 5 m^3/ha/yr must be a minimum estimate. In new yield tables from Skogforsk the production in unthinned Norway spruce plantations has varied from about 6 m^3/ha/yr in site index class G14 to 15 m^3/ha/yr in site index G26, these increments being attained at 100 to 60 years, respectively (Øyen 2002). In Sitka spruce the yield has varied from 12.0 to 32.0 m^3/ha/yr in yield class S14 to S29, respectively (Øyen 2005). The latest increment figures for Norway spruce plantations from the 1990s (NIJOS 2003) display 1.7 mill m^3. By applying yield figures of 8.5 m^3/ha/yr in W Norway and 4.5 m^3/ha/yr in N Norway the spruce plantations will yield a total of about 2.2 mill m^3 per annum. Nersten (1981) indicated that the yield from spruce plantations in W Norway would reach a potential harvesting level of about 0.8 mill m^3 in 2020 and 2.7 mill m^3 in 2060, although these predictions are highly dependent on the investment programs. Therefore, with a further stabilization of the spruce area such as that seen recently, it seems likely to expect that the spruce plantations in the afforestation areas will yield slightly above 2.0 mill m^3.

The present annual harvested volumes are about 0.15 mill m^3 in Northern Norway and 0.25 mill m^3 in Western Norway, i.e. the potential for gradually increasing the cutting is substantial. An interesting development is that 80–90% of the present commercial harvesting takes place in the productive spruce plantations, and that the spontaneous pine and broadleaves seem to be of decreasing economic importance.

Benefits of afforestation

Worldwide, economic development theory provides a basic rationale for tree planting for both industrial and non-industrial purposes (i.e. Westoby 1987, Seip 1996). In Norway the rationales of afforestation could generally be confined to:

1) *Increase of forested land and larger growing stock*. More wood resources are meant to offer more possibilities and flexibility for wood-using industries; adding industrial value in the forestry sec-

tor, and will also strengthen the farmers' possibilities for higher income and maintaining a rural 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 economic rationale may also be confined to import substitution, less dependency on imports or to generate a larger export income (i.e. Lunnan et al. 2003).

2) Subsidizing tree planting in larger reforestation programs will *stimulate the local economy*, it will increase tax income to local communities, and it will stimulate the demand for labour, for instance by forest nurseries, transportation and services/management (Opheim 1972, Hoffmann 1974, Opheim 1997, Øyen 1999, Øyen 2004).
3) Afforestation will offer *"multiplier effects"* by stimulation of labour in other sectors; services, road building, 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 (i.e Pettersen 1972, Lund 1973, Stuanes 1974, Stuanes 1975, Fagerås et al. 1975). With a lower level of labour involved in forest management, it is likely that these effects have decreased during the last few decades.
4) *Additionally,* environmental concerns prompted reforestation work for:
   - Soil, snow and slope stabilization.
   - Windbreakers, to protect agricultural crops and settlements.
   - Recreation and landscape values, promotion of public health.
   - Protection of overutilization of spontaneous forests.
   - Storage of carbon.
   - More flexibility in the energy market.

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. Investments decisions were primarily made on the basis of discounted net benefit. However, state investments of intervention in afforestation areas could barely be justified by commercial returns alone but are also dependent on environmental and social benefits. Other outputs have become increasingly important. Most recently, a study by Willis et al. (2003) found that British forests generated non-market benefits equivalent to £1,000 million per annum. Although 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 heavy intermixed with other societal activities. Complex plantation forestry in reforestation areas, designed to maximize social benefits rather than wood production per se, are still under development in Norwegian afforestation areas (i.e. Fjeld 1997) – as in afforestation areas elsewhere (i.e Humphrey et al. 2000).

Since most plantations were established in the 1960s and 1970s we expect a large increase in harvestable volume around 2020. In the meantime a wide range of policy tools should be considered to increase the benefits from afforestation; i.e. further investments in infrastructure, management options and silviculture for new or prolonged rotations, forest rent and taxation policy, knowledge transfer, research, education and training, restoration and better combined land-use, how to manage plantations to optimize their value as wildlife habitat, increase vitality of small scale companies, etc.

Challenging times lie ahead. International competition will keep 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 and governance. How to better affect rural business activities in a positive way, which is necessary for an efficient outcome of the afforestation programs, is a crucial question deserving further research and development. 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 commercial interesting forest resources.

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Sammenfatning

AFFORNORD er et fællesnordiskt projekt med deltagere fra alle de Nordiske land. Projektets formål er at belyse indflydelsen af beskovning på ökosystemer, landskab og regional udvikling. Dette göres primært ved at danne et netværk af allerede eksisterende projekter på de forskellige fagområder som hörer under projektet. Projektet er financieret af MJS, NEJS og BU (det nordiska miljöhandlingsprogram).

Grundprincippet i AFFORNORD er at sammenligne skov, landskab og samfund i forskellige nordiske land som har lignende samfundsstruktur, men er på meget forskellige nivåer med hensyn til beskovning og brug af skoven. Island, Færöerne, Danmark og dele af Norge og Svergie var, i tidens löb, i höj grad avskovede, mens resten af Skandinavien bibeholdt sin skov. I Danmark, Norge og Svergie har man opbygget skovresursen igen, primært med det formål at anskaffe råmaterialer for industrien. På Island har man begyndt på extensive beskovningsprogrammer og lignende udvikling synes at være lige om hjörnet på Færöerne. De store ligheder mellem de nordiske land samtidig med at de er på meget forskellige nivåer med hensyn til beskovning og brug af skoven giver spændende forskningsmuligheder og muligheder at lære af hindandens erfaringer.

AFFORNORD ordnade en internationell konferans om effekten av beskovning på ekosystem, landskap og regional udvikling i Reykholt, Island i dagene 18–22 Juni 2005 med 90 deltagare fra 15 land. Denne bog indeholder 43 videnskabelige artikler som blev presenteret på denne konferans.