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FOREST MANAGEMENT AND SILVICULTURE IN THE NORTH- BALANCING FUTURE NEEDS

Book of abstracts for the conference in Stjørdal, Norway, September 6-8, 2011

Editors: Aksel Granhus, Kjersti Holt Hanssen and Gunnhild Søgaard

NORSK INSTITUTT FOR SKOG OG LANDSKAP

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Cover Photo: Mountain forest at Skarseterlia, Norway, Dan Aamlid, Skog og landskap

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SAMMENDRAG

I denne rapporten presenteres sammendrag (abstracts) av foredrag og plakater som ble presentert under konferansen "*Forest Management and Silviculture in the North – Balancing Future Needs*". Konferansen ble arrangert 6-8 september 2011 i Stjørdal, og samlet over 50 deltakere fra til sammen 7 land. Norsk institutt for skog og landskap var vertskap for arrangementet, som ble initiert i fellesskap av IUFRO WP 1.01.01 *Boreal forest silviculture and management* og SNS-nettverket *Sustainable forest management in northern Fennoscandia* (NORFOR).

SUMMARY

In this report, the oral and poster contributions of the scientific conference "*Forest Management and Silviculture in the North – Balancing Future Needs*" have been compiled. The conference was arranged 6-8 September 2011 in Stjørdal, Norway, gathering more than 50 delegates from seven countries. The conference was hosted by the Norwegian Forest and Landscape Institute and was initiated jointly by IUFRO WP 1.01.01 *Boreal forest silviculture and management* and the SNS network group *Sustainable forest management in northern Fennoscandia* (NORFOR).

Nøkkelord:	Biodiversitet, flerbruk av skog, karbonbinding, klimaendring, skogbruk, skogproduksjon, skogskader, skogskjøtsel
Key words:	Biodiversity, carbon sequestration, climate change, forest management, global warming, multiple-use forestry, pathogens, pests, silviculture
Andre aktuelle publikasjoner fra prosjekt:	.


FOREST MANAGEMENT AND SILVICULTURE IN THE NORTH
– BALANCING FUTURE NEEDS

CONTENT:

* Invited keynote presentations

1. INTRODUCTION

Boreal forest management and silvicultural practises face new challenges in a changing world. The predicted climate change, increasing demands for energy, increasing populations which needs areas for recreation activities, and the importance of the forest ecosystems for maintaining biodiversity and environmental services all influence silviculture and management.

The northern forest ecosystems can play a vital role in mitigating climate change, both by being a significant carbon sink, but also by providing a renewable source of energy. Silviculture aiming at maximising biomass production for energy and carbon sequestration may be one important means to face climate change. However, silvicultural decisions might also have important implications for other services provided by the forests, including biodiversity, recreation, or other types of economic activity such as reindeer husbandry etc. This raises the question on how to manage and tend our forests to best achieve the right balance between these different, and possibly conflicting, objectives.

A changing climate will influence the duration of the growing season, soil processes and nutrient availability, as well as the risk of injury and calamities by biotic and abiotic factors. This is particularly true in the boreal zone, which most likely will face major changes in climatic conditions during the coming decades. In a warmer climate, insects and pests seem to disperse at a fast pace, posing new or increased problems for forest management. Climate change also creates new challenges for choosing the right species and provenances as well as the best silvicultural methods for regeneration and tending of young stands. Exploring the effects of treatments and management strategies aimed at sustainable biomass production in a changing climate thus remains an important research task.

Forest policies, regulations and certification schemes can also play a large role in how well forests can contribute to mitigation of climate change, and how quickly managers can react to produce the best compromises among wood harvesting, intensive plantations, biomass production, ecosystem functions and ecological reserves. Forest policies may thus need to be adjusted to meet intended objectives.

These important issues set the background for the scientific conference "*Forest Management and Silviculture in the North – Balancing Future Needs*", arranged 6-8 September 2011 in Stjørdal, Norway. At this event, more than 50 delegates from seven countries were gathered to discuss silvicultural solutions needed to sustain the range of forest services required by society in a changing world.

The conference focussed on the following main themes:

1. Climate change: effects on productivity and carbon sequestration in northern forests.
2. Insects and pathogens in northern forest systems under global warming - consequences for forest production and implications for silviculture.
3. Cost-effective regeneration, pre-commercial thinning and young stand management to maintain or increase biomass production of northern forest ecosystems.
4. Developing adaptive silvicultural systems to maintain biodiversity values and production levels.
5. Reducing conflicts between wood production and non-timber values such as reindeer husbandry, berry production and recreational activities.
6. Implementing coherent forest policy and certification schemes that are consistent with forest productivity, stand management, climate mitigation and biodiversity goals.

The conference was organised jointly by IUFRO WP 1.01.01 *Boreal forest silviculture and management* and the SNS network group *Sustainable forest management in northern Fennoscandia* (NORFOR). The Programme Committee consisted of the following persons:

Prof. Urban Bergsten	(Swedish University of Agricultural Sciences)
Dr. Charlotta Erefur	(Swedish University of Agricultural Sciences)
Dr. Aksel Granhus	(Norwegian Forest and Landscape Institute)
Dr. Kjersti Holt Hanssen	(Norwegian Forest and Landscape Institute)
Dr. Mikko Hyppönen	(Finnish Forest Research Institute)
Dr. Risto Jalkanen	(Finnish Forest Research Institute)
Prof. Victor Lieffers	(University of Alberta, Canada)
Dr. Ulf Sikström	(Skogforsk, Sweden)
Dr. Gunnhild Søgaard	(Norwegian Forest and Landscape Institute)

The organizers would like to thank the Norwegian Ministry for Agriculture and Food for supporting the conference with funding. Economic support was also provided by the County Governor of Nord-Trøndelag County. The County Governor also assisted with the planning and organizing of the field trip to Stiklestad and Rør- og Langvann on the second day of the conference.

It is our hope that this conference will contribute to enhanced future cooperation between researchers and managers interested in the silviculture of the northern forests, enabling us to better address issues of common interest. In this book, the oral and poster contributions of the conference have been compiled.

Ås, August 2011

Aksel Granhus Kjersti Holt Hanssen Gunnhild Søgaard

2. CONFERENCE PROGRAM

Monday	***September 5***	
19:00		Registration
19:00		Ice-breaker in the hotel bar

Tuesday	***September 6***	
08:30-09:00		Registration
09:00-09:05	Gunnhild Søgaard	Welcome by Coordinator of IUFRO WP 1.01.01 Boreal forest silviculture and management
09:05-09:15	Inge Ryan	Welcome speech by the County Governor of Nord-Trøndelag
09:15-09:30	Arne Bardalen	Opening of the conference by the director of the Norwegian Forest and Landscape Institute

Insects and pathogens in northern forest systems under global warming - consequences for forest production and implications for silviculture

Moderator:	*Gunnhild Søgaard*	
09:30-10:00	K. Dave Coates	<u>Keynote</u>: Silviculture in a changing world: reflections from recent disturbances in British Columbia, Canada
10:00-10:20	Risto Jalkanen	Pathogens and pests in changing environment and implications to northern silviculture
10:20-10:50	Ulf Sikström	*Pinus sylvestris* stands infested by *Gremeniell abietina* - silvicultural implications
10:50-11:10		*Coffee break*

Climate change: effects on productivity and carbon sequestration in northern forests

Moderator:	*Ulf Sikström*	
11:10-11:40	Sune Linder	<u>Keynote</u>: Climatic and nutritional constraints to growth of Boreal forests
11:40-12:00	Victor Lieffers	Fertilization of lodgepole pine stands in Alberta: uptake, efficiency and snow damage
12:00-13:00		*Lunch*
13:00-13:20	Raimo Sutinen	Soil chemistry contributes to alpine spruce treeline in Finnish Lapland
13:20-13:40	Limin Dai	Climatic factors affecting the radial growth of Korean pine along an altitudinal gradient at Changbai Mountain, Northeast China
13:40-14:00	Richard W. Lucas	The long-term supply of base cations in Swedish forests: evaluating with empirical data
14:00-14:20		*Coffee break*

Cost-effective regeneration, pre-commercial thinning and young stand management to maintain or increase biomass production of northern forest ecosystems

Moderator:	*Kjersti Holt Hanssen*	
14:20-14:50	Matti Sirén	<u>Keynote</u>: Cost efficient regeneration and young stand treatment - challenges and possibilities
14:50-15:10	Paavo Närhi	Long-term effect of site preparation on soil quality at high elevation boreal forest
15:10-15:30	Kristina Ulvcrona	The effect of intensive fertilization on height development in young unthinned Scots pine (*Pinus sylvestris* L.) stands
15:30-15:50	Aris Jansons	Annual height growth development of Scots pine and hybrid aspen
15:50-16:00	Organizers	Practical information about field trip and poster session.
17:00-18:30		Poster session
19:00		*Conference dinner*

Wednesday	***September 7***	Field trip
Thursday	***September 8***	

Cost-effective regeneration, pre-commercial thinning and young stand management to maintain or increase biomass production of northern forest ecosystems (continue)

Moderator:	*Risto Jalkanen*	
08:30-08:40		Opening, day 3
08:40-09:00	Bernt-Håvard Øyen	Thinning in Central Norway. Results based on long-term trials
09:00-09:20	Pentti Niemistö	Effect of thinning intensity on biomass production and economy of growing *Betula pubescens* stands on peatland in Northern Finland
09:20-09:40	Kjersti Holt Hanssen	Short and long-term effects of whole-tree thinning on forest growth
09:40-10:00		*Coffee break*

Developing adaptive silvicultural systems to maintain biodiversity values and production levels

Moderator:	*Risto Jalkanen*	
10:00-10:30	Victor Lieffers	Keynote: Adaptive silvicultural systems to maintain biodiversity and production levels
10:30:10-50	Amalesh Dhar	Competitive Interactions of aspen – lodgepole pine Mixedwoods in a sub boreal forest: implications for reforestation policy and practices in British Columbia (BC)
10:50-11:10	Tommy Mörling	Volume yield of Norway spruce and downy birch grown in mixed or pure stands under boreal conditions
11:10-11:30	Kjell Andreassen	Adaptation of practical silviculture in a changing world - feasibility and effects on forest production and economy for some forest management systems in a boreal mountain forest
11:30-12:30		*Lunch*

Reducing conflicts between wood production and non-timber values such as reindeer husbandry, berry production and recreational activities

Moderator:	*Aksel Granhus*	
12:30-13:00	Seija Tuulentie	Keynote: Reducing conflicts in the use of natural resources: from facts to frames
13:00-13:20	Anu Akujärvi	The effects of forestry and reindeer grazing on the coverage and biomass of ground lichens
13:20-13:40	Mikko Hyppönen	Sustainable use of forests in Finnish upper Lapland - a case study
13:40-14:00	Ville Hallikainen	Towards combining forestry and tourism in Finland: Forest landscape preferences of international tourists in northern Finland
14:00-14:20		*Coffee break*

Implementing coherent forest policy and certification schemes that are consistent with forest productivity, stand management, climate mitigation and biodiversity goals

Moderator:	*Aksel Granhus*	
14:20-14:50	Anne Sverdrup-Thygeson	Keynote: Forestry, biodiversity and ecosystem services: critical issues and relevant policies
14:50-15:10	Gunnhild Søgaard	Contrasting policy targets? - evaluation of policy instruments and certification schemes in Norwegian Forestry
15:10-15:30	Sybille Haeussler	Adapting forestry to climate change in British Columbia's central interior
15:30-15:40	Aksel Granhus	Closing

3. LIST OF DELEGATES

Name	Affiliation	Country
Akujärvi, Anu	Finnish Environment Institute (SYKE)	Finland
Andreassen, Kjell	Norwegian Forest and Landscape Institute	Norway
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Aamlid, Dan	Norwegian Forest and Landscape Institute	Norway

4. ORAL PRESENTATIONS

THE EFFECTS OF FORESTRY AND REINDEER GRAZING ON THE COVERAGE AND BIOMASS OF GROUND LICHENS

Akujärvi, A.[1], Hallikainen, V.[2], Hyppönen, M.[2] & Mattila, E.[2]

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[2] The Finnish Forest Research Institute (Metla), Finland. ville.hallikainen@metla.fi, mikko.hypponen@metla.fi, eero.mattila@metla.fi

Reindeer lichens (*Cladonia spp.*) are the most important winter forage of domestic reindeer. The amount of reindeer lichens has decreased dramatically in the Finnish reindeer herding area during the last decades [1, 2]. So far the inventories have only been carried out inside the reindeer management area where reindeer husbandry and forestry are practised together. It has not been shown without dispute how the different livelihoods affect the amount of reindeer lichens. The purpose of this study was to investigate how forestry and reindeer grazing affect the coverage and biomass of ground lichens in Finnish Lapland. In the dataset there were altogether 50 study areas. The field measurements were taken from both sides of the fence and the grazed and ungrazed sites were compared in the analysis (Fig.1). The coverage and biomass of the ground lichens were modeled using linear mixed effects models.

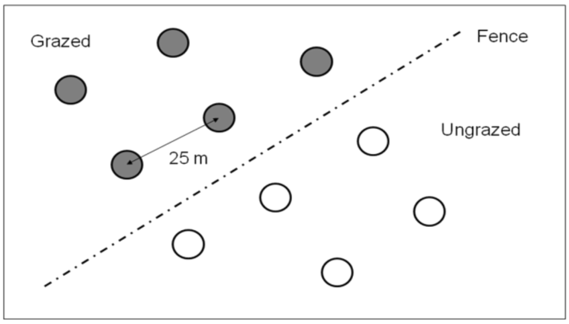

Figure 1. The experimental set. Five sample plots (d = 25 m) were placed on both sides of the fence. The stand properties and the plant species cover were measured on the plots.

In the lichen coverage model grazing and the stand development class were the most significant explanatory variables. The predicted coverage of the ground lichens was 7 % and 38 % in the grazed and ungrazed sites, respectively. The interaction of grazing and the stand development class was a significant explanatory variable at about 5% risk level. In the grazed sites, the coverage of the ground lichens in the seedling stands and in the young and advanced thinning stands was approximately 30 % of the lichen coverage in the mature stands (Fig. 2). In the ungrazed sites, the lichen coverage in the young and advanced thinning stands was approximately 65 % of the lichen coverage in the mature stands (Fig. 2). The coverage of the ground lichens decreased when the crown coverage of the stand increased.

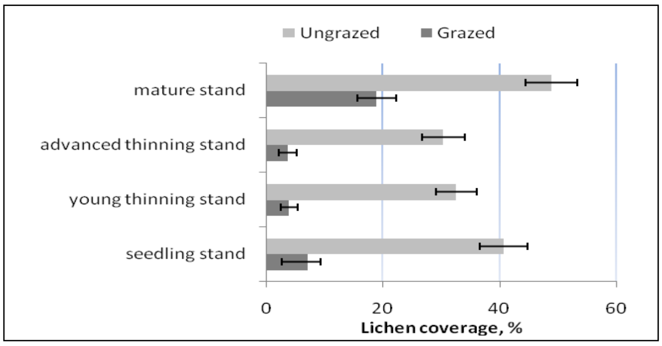

Figure 2. The predicted lichen coverage ± its standard deviation in the grazed and ungrazed sites.

In the lichen biomass model, grazing and the temperature sum (d.d.) were the most significant explanatory variables. The biomass of the ground lichens was 190 kg ha^{-1} and 3600 kg ha^{-1} in the grazed and ungrazed sites, respectively. The biomass of the ground lichens decreased as the temperature sum as well as the crown coverage of the stand increased. The stand development class and the interaction of grazing and the stand development class were also significant explanatory variables in the biomass model. In the grazed sites, the lichen biomass in the seedling stands and in the young and advanced thinning stands was 30-40 % of the lichen biomass in the mature stands (Fig. 3). In the ungrazed sites, the lichen biomass in the mature stands was significantly bigger than the biomass in the advanced thinning stand (Fig. 3). Both the coverage and the biomass of the ground lichens were bigger in the sandy soils than in the moraine ones.

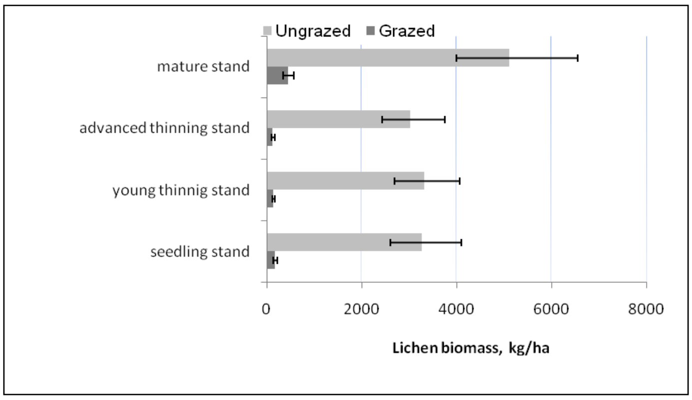

Figure 3. The predicted lichen biomass ± its standard deviation in the grazed and ungrazed sites.

The reindeer winter pastures investigated in this study were in a poor condition based on the lichen coverage and biomass. In the present situation the regeneration of the stands that have reached the maturity would further worsen the condition of the winter pastures.

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ADAPTATION OF PRACTICAL SILVICULTURE IN A CHANGING WORLD – FEASIBILITY AND EFFECTS ON FOREST PRODUCTION AND ECONOMY FOR SOME FOREST MANAGEMENT SYSTEMS IN A BOREAL MOUNTAIN FOREST

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We investigated four forest management systems, clear cutting, mountain forest selective cutting, group system and single tree selection system in two Norway spruce mountain forest stands. The sites are located 50 km southeast of Stjørdal in central Norway 600 m a.s.l., which is about 100 m below the alpine tree line in this region. The background for this experiment was that the forest owner wanted to examine alternatives to clear cutting with silvicultural methods where some trees were left in the stand to protect the regeneration against frost, to maintain the biodiversity and for recreational reasons in these kinds of areas in mountain forest. In twenty 400 m^2 systematically sampled plots we assessed vegetation type, regeneration, diameter of trees > 2.5 cm dbh, tree heights, annual growth from increment cores, tree quality, old stumps and wind throws. In addition, time studies of the four harvesting methods were performed close to each other in the area. Following mean values were estimated in the two stands before cutting: Area 7 hectares, volume 170 m^3 ha^{-1}, mean diameter 23 cm, mean height 18 m, stems 550 ha^{-1}, seedlings 150 ha^{-1}, productivity 3 m^3 ha^{-1} yr^{-1}. The diameter distribution of the two stands was almost similar to a J-shaped curve, but a larger amount of trees in some medium and large diameter classes were observed. Annual increment indicated growth reactions 3 years after harvesting. However, most of the 230 m^3 harvested trees were medium and large sized. The operational costs were estimated according to time studies of the harvesting and extraction of 580 trees. Analyses of net present value, where bare land value and all future revenues and expenses were estimated and discounted backwards to the harvesting year, indicates less profitability in mature stands for group selection and selection system than clear cutting and mountain forest selective cutting. If a more uneven-aged forest is the goal in mature stands, a transition period with a careful mountain forest selective cutting is probably required as the first step, and then a selection system or group selection as the next harvesting.

SILVICULTURE IN A CHANGING WORLD: REFLECTIONS FROM RECENT DISTURBANCES IN BRITISH COLUMBIA, CANADA

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Global climate change and its numerous direct and indirect associated impacts present one of the most daunting issues for future forest management. For example, the lodgepole pine-dominated forests of British Columbia, Canada, have been severely impacted by the current Mountain Pine Beetle (MPB) epidemic [1]. About 17.5 million ha of BC forest land have some level of MPB attack and damage. Roughly 9.5 million of the 22 million hectare operable land base has been attacked. About 50 % of the harvestable timber in central BC is lodgepole pine. The severity of the MPB epidemic has been strongly influenced by warmer winter temperatures in the past decade. The MPB epidemic is the most significant forests management challenge BC has ever faced and has resulted in a major reassessment of forest practices [2]. Simultaneously, a *Dothistroma* needle blight epidemic in northwest BC has been responsible for killing thousands of hectares of pine plantations and has even resulted in the death of mature trees, which is unprecedented. The *Dothistroma* needle blight is a sobering example of indirect effects of climate change [3]. The outbreak has occurred during a prolonged period of above-average summer precipitation. An increase in summer precipitation would more typically be thought of as beneficial for forests, but that increase in moisture has improved the conditions for a pathogen that has far outweighed any benefits. Lodgepole pine, considered a favoured species and planted extensively, is now a major restoration liability in many parts of BC.

The discipline of silviculture has strong traditions that have focused on tree- or tree-related issues such as reproduction methods, provenance testing, growth and yield prediction and development of planting, tending and harvesting techniques. Forest management has tended to follow an agricultural approach of choosing best treatments to optimize any given silvicultural practice (e.g., site preparation method, stock type selection, planting density, thinning regime). Traditional approaches to forest management and silviculture are challenged by the increased variability and uncertainty in environmental, biological, economic, and social conditions associated with climate change. Silviculture must strive to maintain resilience and adaptability and diversify forests to mitigate unexpected negative effects of climate change on biodiversity and forest productivity. We can no longer assume our forests are not impacted by influences beyond their boundaries or that tree species we select will survive and grow as they did in the past. The old world-view of nature being a rather static and predictable system must be replaced by a view which emphasizes continuous change and uncertainty.

As our scientific understanding of forests continues to evolve, we gain more and more appreciation of the importance of structural, functional and compositional heterogeneity, variability and complexity for forest development and for the sustainable provision of ecosystem goods and services, including commodity production. We now recognize the importance of a broad set of ecosystem structures of forests including the abundance and species of standing live and dead trees, other plants, and the presence of downed wood above and belowground in maintaining productivity, biodiversity, and dynamics of forests. It is now clearly understood that forests are not only heterogeneous and variable, but also very dynamic, exhibiting many of the characteristic of complex adaptive systems [4, 5]. Forests contain many biotic and abiotic elements interacting across different levels of organization with interacting feedback loops. Changes in forest dynamics are driven by bottom-up linkages and interactions that bridge different temporal, spatial, and hierarchical scales. Such interactions can be circular, non-linear or exhibit threshold behaviours and they can be influenced by random events. Dynamic changes, and not stable equilibria, are the rule, rather than the exception. We must think about how forests are put together as adaptive systems and how we might deliberately create complex forest mosaics that are pre-adapted to climate change.

In BC, two globally significant forest pest epidemics have been linked to climate change. Silviculture in BC now faces the challenge of maintaining a flow of forest products while at the same time ensuring the ability of forests to adapt to diverse and unexpected future conditions. These changes and the associated stresses imposed on forested ecosystems are an obvious example of the need to think about how we manage forests.

Managing forests involves the interaction of a vast number of ecological and socio-economic processes within and across a wide range of spatial and temporal scales. Forest managers need new tools, skills and knowledge to meet increasingly diverse and sometimes even contradicting policy goals. Adaptability and resilience are general criteria for evaluating the success of policy goals in forests managed as complex adaptive systems. Silvicultural practices needs to be flexible, adaptive, and experimental and should, at a minimum, aim to increase resistance to change, promote resilience to change, and facilitate the ecosystem's ability to prepare (or adapt) for changing conditions.

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3 Woods, A., Coates, K.D. & Hamann, A. 2005. Is an unprecedented *Dothistroma* needle blight epidemic related to climate change? *BioScience* 55(9):761-769.

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5 Puettmann, K.J., Coates, K.D. & Messier. C. 2009. *A Critique of Silviculture: Managing for complexity.* Island Press, Washington, DC.

CLIMATIC FACTORS AFFECTING THE RADIAL GROWTH OF KOREAN PINE ALONG AN ALTITUDINAL GRADIENT AT CHANGBAI MOUNTAIN, NORTHEAST CHINA

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Exploring the effects of climatic factors on the growth of dominant tree species in various forest types will help reveal how stand composition and structure will be impacted by climate change in the future. The growth-climate relations of a particular dominant tree species across altitudinal gradients may provide useful insights into the role of climate change on forest ecosystems. Increased forest growth rates and forest productivity caused by climate change has been documented in central and Northeast China [1, 2]. However, studies carried out at tree line forests and for spruce-fir forest have not found an increase in forest productivity, suggesting that growth trends at different altitudes may not follow a uniform pattern. Much previous research has focused on long-term growth trends of the broad-leaved and Korean pine (*Pinus koraiensis* Sieb. et Zucc) mixed forest type in Northeast China due to the high economic value and wide distribution of Korean pine in the region. At the same time, few studies have addressed the growth-climate relationships of Korean pine.

The objective of this study was to investigate the relationship between climatic factors and the radial growth of Korean pine along an altitudinal gradient using dendroclimatic analysis. Specifically, we investigated the growth of Korean pine at its upper, middle and lower altitudinal distribution zones by: (1) determining climatic factors correlated with radial growth of Korean pine; (2) assessing the variation of' this species' responses to climatic factors in relation to altitude (from 700 to 1450 m above sea level (asl); and (3) discussing implications for Korean pine growth and distribution at Changbai Mountain in response to climate change.

The study area is located in Northeast China on the northern slope of the Changbai Mountain Natural Reserve (41°31′~42°28′N, 127°9′~128°55′E). According to the different stand types, three sample sites – BP (broad-leaved and Korean pine mixed forest), DC (dark coniferous forest), and BD (ecotone linking BP and DC) – were selected along an altitudinal gradient from 500 to 1 450m asl. For each stand, three 20 m × 90 m plots were established and approximately 20 relatively large canopy trees were sampled (if the number of Korean pines available for dendrochronology analysis was less than 20, then trees outside the plots were sampled). Paired increment cores were taken at breast height (1.3m) using increment borers from opposite directions; in a few instances (N= 6) where the tree was partially rotten, only one core was taken.

Each ring-width series was detrended by fitting a negative exponential curve and a straight line with a negative slope using the ARSTAN program, and then three RES chronologies were developed (Fig. 1) and was used to estimate the relationship of tree radial growth and climate factors.

Response function analysis indicated that in BP plots monthly precipitation in combination with minimum temperature explained more variation in radial growth (r^2=0.35) (depicted in Fig. 2). Significant variables included March (t) minimum temperature and May (t), June (t) and July (t-1) precipitation. In plot BD precipitation with minimum temperature also explained more variation in radial growth (r^2=0.33) than did monthly precipitation paired with either maximum or mean temperatures.

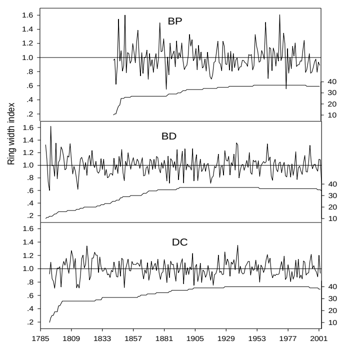

Figure.1. Residual chronologies from plot BP, plot BD and plot DC and corresponding sample depth (number of radii).

Significant variables included September (t) and November (t-1) precipitation. In plot DC, monthly precipitation in combination with minimum temperature also explained more variation in radial growth (R^2=0.31) than did monthly precipitation paired with either maximum or mean temperatures. Significant variables included February (t) minimum temperature and February (t), March (t) and September (t) precipitation

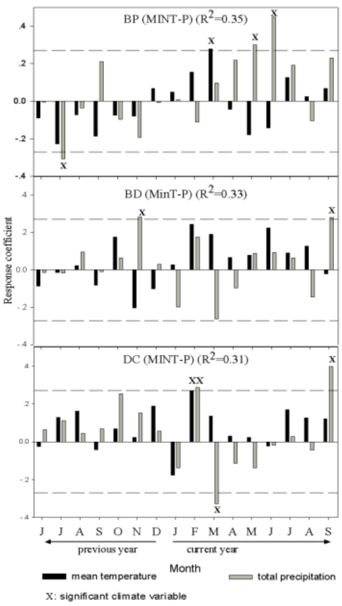

Figure.2. Response function coefficients between the residual chronology and monthly precipitation and minimum temperature for three sites at Changbai Mountain.

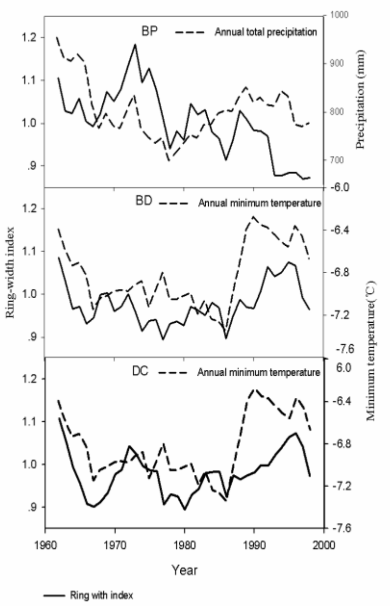

Figure 3. Trend analyses for 5-year running average of Korean pine ring-width indices and total precipitation (plot BP) and annual minimum temperature (plots BD and DC) for the period of October (t-1) to September (t) during the period of 1960-2000 at Changbai Mountain.

Five-year running average series were also used for analyzing growth-climate trends based on three RES ring width indices (Fig. 3). The most significant correlation of the 5-year running averages of ring width indices and 5-year annualization climate variation for the period of October (t-1) to September (t) were found between RES and precipitation in plot BP (r=0.38, p=0.015); between RES and minimum temperature in plot BD (r=0.63, p<0.0001); and between RES and minimum temperature in plot DC (r=0.58, p<0.0001). Based on the standardized data of precipitation and minimum temperature, regression equations were developed and were used to simulate the growth trends under climate change (Fig. 4)

The sensitivity of Korean pine to climatic factors decreased with increasing elevation. Contrary to the general wisdom that sufficient precipitation in the Changbai Mountain area negates its role as a key factor influencing tree growth, we found that precipitation significantly affected Korean pine radial growth. More specifically, in its distribution zone at lower elevations Korean pine was much more affected by precipitation; while at the upper limit of its higher elevation zone it was much more affected by minimum temperature. Radial growth at lower elevations decreased with increasing elevation, but would increase at higher elevations under the global change characterized by warming and drought. Under such a scenario, the dominance of Korean pine at higher elevations may be enhanced. These results have demonstrated that the effect of climatic variation on Korean pine growth differed with elevation at Changbai Mountain.

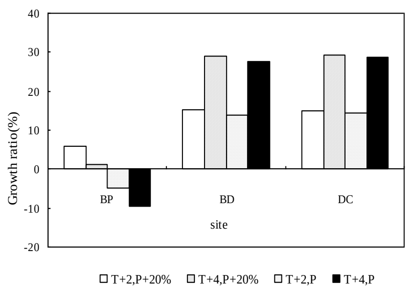

Figure.4. Korean pine radial growth trends under four climate change scenarios (T+2, P+20%; T+4, P+20%; T+2,P; T+4,P) by regression analysis of total precipitation and annual minimum temperature and Korean pine ring-width index in plots BP, BD, DC.

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VOLUME YIELD OF NORWAY SPRUCE AND DOWNY BIRCH GROWN IN MIXED OR PURE STANDS UNDER BOREAL CONDITIONS

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Creating mixed species stands have been of interest for forest research for more than hundred years due to the potential of increased biodiversity, wind stability, and growth. In Scandinavia the mixture of deciduous trees, especially Silver birch (*Betula pendula* Roth.) and Downy birch (*Betula pubescens* Ehrh), in Norway spruce (*Picea abies* (L.) Karst.) stands has been of interest due to an often spontaneous regeneration of birch. However, the results on total volume yield from mixing these species are inconclusive [1, 2, 3, 4, 5]. One of the explanations given for the results from simulations and field experiments has been a mixing effect due to differences in ecological niches [4]. When two species are mixed, there can be one of three outcomes in terms of productivity. First, one or both species grow less than when grown alone, i.e. a competition effect. Secondly, both species grow as they would have done if grown alone, i.e. they grow independent of each other. Finally, one or both species grow better than when grown alone.

The aim of the present study was to quantify 1) the change in growth of the spruces caused by the birch shelterwood, and 2) the change in growth of the birches caused by the spruce undergrowth, during 33 years after experiment establishment.

The experiment was established in 1973 north of Vindeln in Northern Sweden (Lat. 64º 18' 30'' N, Long. 19º 44´ 55'' E) on a flat, mesic-moist site at altitude 260 m. After prescribed burning the area was regenerated by direct seeding in 1938, with a mix of Scots pine (*Pinus sylvestris* L.) and Norway spruce seeds. A dense natural regeneration of birch (*Betula pubescens* and *Betula pendula*) appeared during the following years. A birch cleaning was performed in 1951. The experiment comprised 14 plots of 0.1 ha, grouped in 7 pairs of plots with different treatments. Each plot was surrounded by a 5-10 m wide buffer zone with the same treatment as the net plot. The treatments were dense (B6 = 600 stems ha^{-1}), sparse (B3 = 300 stems ha^{-1}) or no birch shelterwood, combined with no (zero,) or 1 500 stems ha^{-1} spruce undergrowth (S), resulting in a total of five combinations – B6, B3, B6S, B3S, S. After treatment the shelterwoods consisted of 96% birch and 4% pine. The experiment was unbalanced, i.e. the number of replicates differed between treatments, such that there were two replicates for all treatments except S and B6S, which had four replicates.

Re-measurements of the experiment were made in 1980, 1985, 1990, 1994, 2001 and 2006. At each measurement occasion all trees were cross-callipered at 1.3 m (dbh) to the nearest mm. Total height and height to the lowest living branch was measured to the nearest 0.1 m on sample trees, randomly selected among living, undamaged trees of all species.

In the statistical analyses of hypothesis 1 the total spruce yield (YS) was modelled as:

$$YS = f(hS, VB)$$

where hS was the mean height of the spruces, and VB the standing volume of birch, at the start of the experiment.

In the analyses of hypothesis 2 the total birch yield (YB) was modelled as:

$$YB = f(hB, VB, DS)$$

where hB is the mean height of the birches at the start of the experiment, and DS is a dummy variable for presence of spruce (1) or not (0).

Total volume production of Norway spruce during the observation period was not significantly affected by the presence of birch shelter trees but the total volume production of birch was significantly lower when an under-storey of spruce was present (Fig. 1)

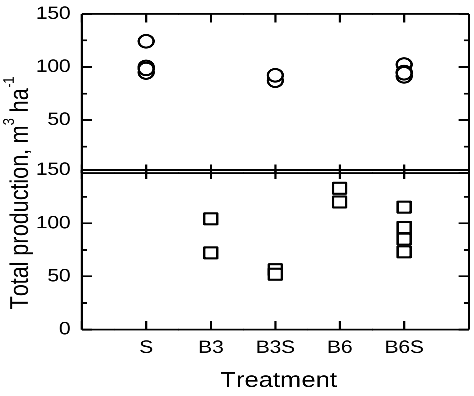

Figure 1. Total volume production of Norway spruce (circles) and Birch (squares) for the treatments. S= spruce, B= Birch, 3= 300 stems shelterwood, 6= 600 stems shelterwood.

Seven years after experiment establishment, at age 43, the mean height of spruce was about 5 m and that of birch about 15 m. In autumn 2006, at an age of 69 years, the top height of spruce was in average 13.7 m and of birch in average 21.2 m. Height increment of spruce was not significantly affected by the treatments. Height/diameter-ratio of Norway spruce was significantly affected throughout the observation period, such that the spruces became increasingly slender with more birch shelter trees.

The increase in total volume production, i.e. the birch production was additional when birch was present as shelter wood, indicating a positive mixture effect, was in accordance with several other studies [4, 5]. On the other hand, birch production showed a reduced production as a response to the presence of a spruce under storey indicating negative mixture effect. However, even though this study was one of very few using controlled experimental design, the effect may differ with site conditions and age [2, 4]. Further studies are needed both to establish the effects on productivity of mixing species and to explore the processes behind it.

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ADAPTING FORESTRY TO CLIMATE CHANGE IN BRITISH COLUMBIA'S CENTRAL INTERIOR

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The Bulkley Valley and Lakes districts of British Columbia's central interior have a sub-boreal climate and a glaciated, rolling landscape similar to southern Fennoscandia. The forests have a mix of boreal (white spruce, black spruce, trembling aspen, paper birch, balsam poplar) and Rocky Mountain (lodgepole pine, subalpine fir, Engelmann spruce, Douglas-fir, whitebark pine, black cottonwood) tree species with temperate rainforest species (western and mountain hemlock, western red-cedar, amabilis fir) at the western margins. Silviculture in the region has focused on clearcutting and planting of lodgepole pine and white x Engelmann spruce, with some management of subalpine fir at the highest elevations and Douglas-fir on the warmest, dry sites. The climate and economy are, however, changing rapidly and a series of region-wide shocks (mountain pine beetle epidemic, increases in fires and floods, US housing market collapse) have exposed vulnerabilities in the forest-based economy, motivating local communities to address uncertainties associated with climate change.

The Bulkley Valley Research Centre, a not-for-profit sustainability institute, has undertaken a program of applied research to assist local communities in adapting to climate change, funded mainly through British Columbia's Forest Science and Future Forests initiatives. These projects have included assessing historic climatic variability; producing downscaled climate projections [1,2,]; monitoring the impacts and responses of forest ecosystems and wildlife to large scale disturbances; adapting forest simulation models such as TACA [3]; SORTIE-ND [4] and SELES [5] to project tree regeneration, forest growth and landscape configuration under a range of climate change scenarios; and engaging forest stakeholders in a multi-scale vulnerability and livelihood assessment.

Since 1895, mean annual temperature in British Columbia's central interior has risen over 2^{o}C, while total precipitation has increased 30-40 %. Minimum temperatures have climbed sharply while maximum temperatures are mostly unchanged, resulting in a more temperate climate that is becoming favorable to a variety of non-boreal organisms including pests and pathogens. The region is also strongly influenced by ocean-atmosphere patterns such as El Nino/La Nina Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) and many environmental shifts reported anecdotally and in scientific studies can be linked to these cyclic phenomena.

Monitoring of forest vegetation change and indicators such as woodland caribou and reindeer lichens over a 7-30 yr. period has provided some support for the hypothesis that boreal forest species are declining while temperate species are increasing across the region. Longer-term climatically driven trends are, however, greatly confounded by short- and medium-term responses to ENSO/PDO fluctuations and forest disturbances including wildfire, bark beetles, logging, and tree diseases. Our tentative conclusion from this empirical research is that local-scale variability in how ecosystems respond to climate and disturbance will prove to be an important source of resilience for boreal species in a warmer climate. Active management could allow boreal organisms to persist outside of their historical climate envelope. Whether our society will pursue such management is another matter.

Climate change projections for the region using various IPCC emissions scenarios project a mean annual temperature increase of +1.3 to 2.7^{o}C by 2055, relative to 1961-1990 normals. Total precipitation is projected to increase between 2 and 16 % with most of the increase occurring in winter. The PDO and ENSO are not captured in GCM and could dramatically influence how the transition to a substantially warmer world unfolds. Adaptation strategies will need to be sufficiently flexible to accommodate anything from a semi-arid savanna climate to a mesic temperate forest climate, as well as more extreme weather. The first round of modeling suggests that silvicultural investments that target north aspects, moist topographic positions and higher elevations have the lowest risk of regeneration failure. The next round of modeling (in progress) will address interactions among tree performance, disturbances and forest practices.

Although the challenges and uncertainties caused by climate change may be broadly similar in boreal and northern temperate regions of the world, cultural, institutional and economic differences are likely to influence how governments and local communities respond to these challenges. We hope that the opportunity to share experiences with foresters from other nations will improve our ability to help local communities in British Columbia's central interior adapt wisely.

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SHORT AND LONG-TERM EFFECTS OF WHOLE-TREE THINNING ON FOREST GROWTH

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Introduction

The use of logging residues for bioenergy is encouraged in many countries, due to an increasing demand for renewable energy. However, as needles and branches are nutrient rich, this whole-tree harvesting (WTH) increases the export of nutrients from the site. There is concern that removal of logging residues may cause a long-term reduction in soil nutrient availability, reducing forest growth in the remaining stand. Some studies have shown growth reduction after WTH [1, 2, 3], while others have not found significant effects on growth [4, 5]. The response seems to be variable, and site- as well as species-specific. There is a need for short and long-term growth results to assess the sustainability of intensive biomass harvesting and to understand the processes involved. The objective of this study was to quantify the growth response of Norway spruce (*Picea abies*) and Scots pine (*Pinus silvestris*) to whole-three harvesting at first thinning.

Method

In 1972-1977 a series of eight field experiments was set up in young Norway spruce and Scots pine sites in SE Norway. In the stands, thinning plots using both conventional (CH) and whole-tree harvesting were established, with five replicates of each treatment. The pine and spruce stands were thinned to 800 and 1 100 trees ha^{-1}, respectively. The amount of dry matter and nutrients removed in the thinning was computed, and tree growth was measured each 5th year. In addition, growth was measured every year the first 5 years in the spruce stands. Total study period with all plots intact was 25 years for spruce and 20 years for pine stands. Growth increment was analyzed separately for spruce and pine, using analyses of variance to compare the two treatments.

Results and discussion

For spruce, WTH lead to a decrease in forest growth. The effect was present more or less immediately after thinning, and was still present after 25 years. The average reduction in growth was around 10 % compared to CH after 25 years, if adjusted for initial differences in standing volume. The difference was statistically significant. After 20 years there was a non-significant average growth reduction in the pine stands of 4 %, adjusted for initial differences in standing volume.

The results show that growth reduction in spruce stands after WTH may take place straight after harvesting, and is present at least 25 years after thinning. As decomposition of logging residues takes some years to initialize, we suggest that other factors than differences in nutrient availability must have caused the immediate effect. The effect in pine stands was smaller. Also [6] and [3] found a more explicit growth reduction after WTH in spruce compared to pine stands. When transferring the results to practical silvicultural measures, one should consider that the results are generated under experimental conditions. In practice, a share of the residues is left on site during harvesting, decreasing nutrient loss compared to a total removal of branches and tops.

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COMPETITIVE INTERACTIONS OF ASPEN – LODGEPOLE PINE MIXEDWOODS IN A SUB-BOREAL FOREST: IMPLICATIONS FOR REFORESTATION POLICY AND PRACTICES IN BRITISH COLUMBIA (BC)

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Introduction

Traditionally broadleaf tree species and other competing vegetation have been removed from conifer stands in the central British Columbia interior to promote growth of conifer crop trees. However in recent years strategies for managing mixed broadleaf–conifer stands have been under review. More has been learned about the role of broadleaves in forest ecosystems but specific knowledge about competitive interactions of mixed broadleaf–conifer stands is scarce. To develop effective management strategies for broadleaf – conifer mixtures where softwood timber production is the primary objective, silviculturists require information about the level of broadleaves that can be retained without seriously affecting conifer performance. They also require practical ways of using this information to develop cost-effective treatment prescriptions.
The main objectives of this study were to examine the growth response of pine to varying levels of imposed aspen densities and test the effectiveness of current BC free-growing criteria.

Material and methods

The study site Vama Vama Creek is located about 50 Km east of Prince George in central BC. It is in the warm cool (wk1) variant of the Sub-Boreal Spruce biogeoclimatic zone. Experiment 1 was a completely randomized block design with six nominally different aspen densities (0, 500, 1 200, 2 500, 5 000, and untreated control) each replicated three times. Plots were sampled at establishment and three times between ages 14 to 18 years. At each site, treatment plots measuring 50 m X 50 m in size were established and containing a 5.64 radius (0.01 ha) permanent sample plot (PSP) in an aspen patch nearest the plot centre. Equal numbers of free growing (FTG) and not free growing (NFTG) lodgepole pine were also selected and identified with a unique number in experiment 2. Trees with no aspen within the effective growing space (1 m radius cylinder centered on the pine) were classed as FTG. Crown dimensions, total height and DBH were measured for each pine in 2000, 2002, and 2006. Leaf area index (LAI) was calculated for both FTG and NFTG lodgepole pine. Light measurements were made using a LiCor LAI-2000 Plant Canopy Analyzer (LiCor Inc., Lincoln NB) to identify the light transmission [1]. All analyses were conducted using the statistical package STSTAT version 12®. Competition thresholds were determined based on relationships between lodgepole pine annual diameter increment and aspen density. Thresholds were identified using a ceiling function which described the upper boundary of the data and enveloped at least 95 % of the observations [2].

Results and Discussion

The overall diameter of lodgepole pine generally decreased with increasing aspen density (Fig. 1). However, in this study 5 000 sph (stems ha^{-1}) of aspen appears to be the critical density at which point diameter growth of the pine was significantly (p=0.005) affected whereas 2 500 sph was the threshold density (p=0.168) for not affecting pine diameter. Lodgepole pine diameter growth responds to aspen density treatments suggesting that aspen were important competitors as reduced aspen densities relieved the competitive stress. However, it is uncertain at this time whether the difference will remain or if the results are in part a function of the larger tree size at the time of treatment: stand is currently 22 years old and was treated 10 years previously. Moreover, it should be noted the study was designed to measure the effects of competition rather than to investigate its mechanisms. Therefore we can only hypothesize about reasons behind the different responses.

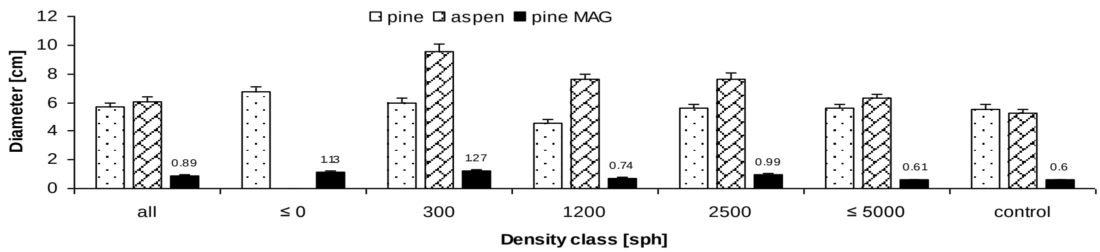

Figure1. Mean lodgepole pine and aspen ground diameter (± SEM) at plot establishment and mean annual pine DBH growth for the year of 2000-2002 (± SEM)

In repeated measures analyses DBH, height and crown volume were not significant when comparing FTG and NFTG lodgepole pine (Table 1). Both FTG and NFTG showed a similar DBH growth response from 2002 to 2006. However tree height of FTG pine was taller than NFTG pine. The crown volume of FTG pine was decreasing with increasing aspen density whereas NFTG pine showed variable responses.

Table 1. Results from repeated measures analyses from 2000, 2001, 2003 and 2006 in ANOVA comparing height, diameter and crown volume for FTG and NFTG pine

Source	SS	DF	MS	F	P
Height	11052.488	1	11052.488	0.237	0.628
Error	3732081.537	80	46651.019		
DBH	108.905	1	108.905	0.069	0.794
Error	127043.915	80	1588.049		
Crown Vol.	51.509	1	51.509	0.083	0.774
Error	49425.698	80	617.821		

ANOVA revealed that LAI was significantly different among density treatments (p=0.003), but not for FTG or NFTG (p=0.614); whereas, DIFN was not significant for density treatments or FTG or NFTG pine (p=0.082 and p=0.500, respectively).The leaf area index (LAI) of the FTG and NFTG pine increased with increasing aspen density. As expected, pine DBH growth increases with the increase of DIFN but the response is not significant. The least DBH and height growth was observed at DIFN below 0.1 in NFTG pine whereas in FTG pine growth did not vary at greater DIFN levels. This study revealed that the leaf area index (LAI) increased with increased aspen density which is consistent with other studies in the boreal forest [3]. Results from this study indicate that the rate of change of DFIN and LAI is similar up to 2500 sph but at densities greater than this both LAI and DIFN change markedly: thus suggesting an aspen density threshold. This suggests that appropriateness of the free growing status at 1 m radius is conservative as the apparent density threshold exceeded the current allowable free-growing guidelines. However, differences in pine performance as a result of the treatments are not well-justified, and we cannot determine whether the current “free-growing” guidelines are biologically appropriate. However the findings from this study will help to determine whether or not the current standards are appropriate for producing the expected outcomes.

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SUSTAINABLE USE OF FORESTS IN FINNISH UPPER LAPLAND – A CASE STUDY

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Introduction

Reindeer husbandry, forestry, wood industry, and nature-based tourism are nowadays the main sources of livelihood in northernmost Finnish Lapland, which is a part of the Sámi homeland. Fishing, hunting, picking mushrooms and wild berries and other forms of gathering are of considerable economic and cultural importance for the local population, as well. However, utilization of the same resources for different purposes in this area has not been free of controversy. The controversy between alternative uses of forests in Upper Lapland has been going on for decades, and some ten years ago, it escalated to a serious conflict. The conflict existed especially between state forestry and reindeer husbandry [1]. For the time being, the conflict has been resolved.

In 2003, when the controversy had escalated to conflict, the Finnish Ministry of Agriculture and Forestry evaluated the situation in the area and concluded that more economic and other forms of research was urgently needed for decision-making purposes. Consequently, the Finnish Forest Research Institute (Metla) initiated a multidisciplinary research program, "Sustainable Use of Forests in Upper Lapland".

The project focused on the generation of scientific knowledge, practical instruments, alternatives and decision support for the planning and organization of land use in the area. The final goal was to create solutions for organizing land use in the area in an ecologically, socio-economically and culturally sustainable way.

Methods

The project had an advisory board on which different interest groups were widely represented. The multidisciplinary project was divided into five sub-projects:

1) economic importance of different sources of livelihood,
2) cultural significance of different livelihoods,
3) relationships between forestry and reindeer husbandry (reindeer-forest models),
4) sustainability and equity of different livelihoods, and
5) development of sustainable, alternate production models for different livelihoods.

The sub-projects included a great variety of methods used in the analyses of ecological, economic, sociological, and cultural studies. For example, general and generalized linear modelling, input-output analyses, qualitative interviews, inquiries, simulations, and multi-criteria decision support methods were used. In the last sub-project, the results of the other four sub-projects were utilized in developing sustainable production models for different livelihoods. The alternate production models were based on different areal cutting levels (300 000, 150 000, 115 000, 80 000 and 10 000 m^3 $year^{-1}$).

Results

The project produced new information about the use of the forests in Upper Lapland. New information was generated about the relationships of the livelihoods, local economic effects of the livelihoods, factors affecting sustainability of the livelihoods, and about the opinions of the inhabitants, tourists, and the members of the advisory board concerning livelihoods, the use of nature, factors affecting the state of reindeer pastures, and ecological, economic, sociological, and cultural effects of the different cutting alternatives. Furthermore, the project generated instruments that are usable in corresponding conflict situations.

According to the results, nature-based tourism was economically an overwhelming livelihood in Upper Lapland. Well-executed interactive and participatory planning of natural resources is, in spite of its problems and weaknesses, a good and necessary means for control management. The inhabitants regarded reindeer herding as the culturally most important livelihood. They also appreciated forestry both culturally and economically, and were generally satisfied with land use distribution of the study area. They considered that the role of Metsähallitus (a state enterprise that administers state-owned land and water areas in Finland) is important especially in forest conservation, but also in wood production for the needs of local upgrading. The respondents regarded the cutting and management of forests as rather positive treatments but they particularly resisted mechanical cutting and site preparation. They emphasized the importance of the local level when making decisions about natural resources.

Fifteen members of the advisory board were interviewed, and by means of a value tree analysis, alternatives and their impacts were examined. Three different groups were recognized in a multi-criteria analysis among the interviewees. The groups emphasized variously employment and income of the local economy, Sámi reindeer management culture, biodiversity, local nature use and recreation, and achievement of consensus. Two of the groups valued highly the cutting alternative of 115 000 m^3 $year^{-1}$ and one of them that of 10 000 m^3 $year^{-1}$.

Discussion and conclusions

The study revealed remarkable shortcomings in knowledge, for example, when estimating the relationships between forestry and reindeer herding and particularly those between forestry and tourism. The shortcomings became exposed in the final stage of the study when comparing the different cutting alternatives with simulations and multi-criteria analysis. Multi-criteria decision analysis was found to be a useful approach to evaluate the economic, ecological, social, and cultural aspects of the intense conflict. Forest management treatments which lessen disadvantages to reindeer herding should be further studied and developed.

The results show that the achievement of consensus is worth reaching from the viewpoints of diversity of livelihoods, local economy and inhabitants' communality. The results also denote that the forests in Upper Lapland can be used fairly in a sustainable way while at the same time taking into account demands of different livelihoods, the continuation of Sámi culture, the safeguarding of biological diversity, and the maintenance of the possibilities to use the nature for recreation. The achievement of consensus prevails in that the sides of conflicting parties are willing to compromise.

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PATHOGENS AND PESTS IN A CHANGING ENVIRONMENT AND IMPLICATIONS TO NORTHERN SILVICULTURE

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Biotic, abiotic and anthropogenic factors affect and stress trees in many ways in Finnish Lapland, where all the native tree species meet their northern and alpine limits. Trees are thus susceptible not only to regional pathogens and pests, but also to various abiotic phenomena, resulting in abiotic disorders or predisposing trees to biotic agents.

The Northern Boreal Zone is an excellent laboratory for observing how the trees and their pests and pathogens interact in the changing environment. Some causal agents are only southern in their occurrence while others infect the scattered northernmost tree specimens. The distribution area of the pathogens and pests expands more readily than that of the host species, the trees. Thus, the changing climate may predispose trees to old and well-known local causal agents, or new pathogens and pests may afflict trees. Further, the occurrence, quantity, and quality of the abiotic disorders may change; e.g. as a result of changes in the harshness of the seasons. To date, abiotic disorders and pathogens have caused the most visible damage to trees in Finnish Lapland, and insect problems have been less important. These relations are expected to undergo changes in the changing environment of the Northern Boreal Zone.

Based on decades-long follow-up and surveys in the area, spatial and economic changes in the role of the major and minor biotic and abiotic phenomena on the northern boreal trees and forests will be evaluated. Their influence on silvicultural practices as well as factors affecting environmental changes is discussed.

ANNUAL HEIGHT GROWTH DEVELOPMENT OF SCOTS PINE AND HYBRID ASPEN

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Height growth is one of the most important parameters, determining competitiveness and productivity of tree. Total length of height growth of trees is determined by growth intensity and length of used growth period. Climatic changes are predicted to increase mean temperatures as well as frequency of unfavourable (for tree growth) meteorological conditions. Aim of the study is to evaluate the annual height growth development and its genetic determination and to assess possibilities to improve adaptation via application of tree breeding.

Height growth has been measured with the 7 day intervals from end of April to beginning of July in clonal trial of Scots pine, established on forest land (*Myrtillosa* forest type) with grafter material in year 1998 in central part of Latvia (latitude 56°44', longitude 24°07'). Altogether 288 ramets from 72 clones with mean height 4.1 m have been used for the study. Height growth measurements with similar frequency have been carried out in hybrid aspen (*Populus tremuloides* x *P. tremula* L.) clonal trial (latitude 56°26', longitude 22°52'), established with material from tissue culture on former agricultural land, in its 5th growing season. Altogether 15 hybrid aspen clones, represented on average by 24 remets were assessed.

Average growth intensity of Scots pine clones at the age of 14 years were 10.1 mm day^{-1}, that reached 18 mm day^{-1} (up to 32 mm day^{-1} for particular remets) during the culmination. Results reveal, that growth intensity, especially in the beginning and end of the growth period, is strongly dependent on genotype – it has similar heritability as tree height (H^2=0.36-0.42 and H^2=0.49 respectively). Total length of height increment is influenced mostly by growth intensity at the culmination and end of growth period (r^2=0.42). Notable difference in height growth dynamics have been found between clones. Results reveal that it is possible to select clones, forming more than 35 % of total length of height increment during relative short period of time (15-20 % of total height growth period) and still heaving average or high total length of height increment. Trait to form proportionally large part of total height increment in short time span, has relative high heritability (H^2=0.30).

Hybrid aspen clones have differences in total length of growth period – from 173 till 191 days, related both to bud burst (from 12 days at earliest stages of this process to 4 days in latest) and leaf coloration. Clones with earlier flush tend also to keep their foliage longer. Total height increment is related to length of growth period (r=0.55) and clones with longer growth period tend to have slightly higher length of height increment.

Height growth intensity reached 16 mm day^{-1} at the beginning and during culmination of growth period. Average temperature was the main driving force of shoot growth intensity (r^2=0.84). Significant difference among clones also was found for this trait.

It can be concluded, that there is notable potential to select trees with long height increment and certain pattern of height growth development and improve the adaptation capacity without compromising productivity of future stands.

ADAPTIVE SILVICULTURAL SYSTEMS TO MAINTAIN BIODIVERSTIY VALUES AND PRODUCTION LEVELS

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There has been more 100 years of development of silvicultural practices that have focused on establishing and culturing forests to produce wood. In recent years, however, there has been increasing interest in maintaining the diversity of plants, insects and wildlife that are found in natural forests. There is growing interest to adapt silvicultural practices to maintain biodiversity as well as wood production. As boreal forests are slow growing and have long rotations, and the wood has only moderate value, managers must keep the costs of silviculture low; less intensive silvicultural practices, however, might be more in tune with encouragement of biodiversity in forests. This paper will address the range of structural, composition and management features that can influence both production and biodiversity. Examples will be gathered from the Canadian and European boreal forest.

Results

Strategies should focus on:

1) **Light -** Managers can manipulate the average intensity and variation of light striking the forest floor. Stands that are fully-stocked, with regular spacing of a dense-canopied species such as spruce will have little light reaching the forest floor. While these stands may have value for thermal cover for some species, such stands will have little understory vegetation except for the most shade tolerant species. However, variation in light can be produced by adding species with lower leaf area density (such as *Populus tremuloides*) or changing the layout of trees to produce gaps in the overstory layer. Further, the time of and the intensity of thinning can have a significant effect on light transmission and the type of understory vegetation that a stand can support.

2) **Stand structure** – Vertical structure in forests influences a variety of features for animal habitat. It can be manipulated by developing stands with different age classes via selection systems, natural shelterwood systems, or leaving mature residual trees at the time of logging (variable retention harvesting). Some vertical structure can also be developed by mixing fast and slow growing species in the same stands.

3) **Dead wood** – Both standing dead trees (snags) and downed logs can be critical habitat for woodpeckers, cavity nesting birds, bats and saproxylic insects, mosses, lichens and tree seedlings. Knowing the mortality rates of trees in variable retention harvest and their rate of fall-down, managers can predict the recruitment of dead wood into stands, a decade or more after logging.

4) **Low impact treatments** - Site preparation and vegetation management can have significant impact on vegetation and tree diversity in stands. Finding simple and inexpensive means to produce seed beds and planting spots, as well as control problem vegetation will have a critical linkage to biodiversity.

5) **Regulations** - Government regulation of silvicultural practices or regeneration standard have a large influence on forest structure; indeed, regulations often give managers little choice in how they can manage forests. Most of the older regulations were developed to promote wood production, often at the expense of biodiversity values. As an example, the 'free-to-grow' standards used extensively across Canada require that hardwoods be removed in the immediate

areas around conifer trees in stands that are planned to be conifer-dominated. This treatment, however, cannot be achieved economically without use of herbicides.

Discussion

One of the key features of biodiversity management is to produce a variety of outcomes, i.e., stands with different species composition and vertical structure spread across the landscape. This approach can be linked with wood production but it will require more planning of silvicultural interventions. Managers and regulators must re-assess all regulations to ensure that they are not in conflict with biodiversity goals.

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CLIMATIC AND NUTRITIONAL CONSTRAINTS TO GROWTH OF BOREAL FORESTS

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Boreal forests occupy approximately one third of the global forested land surface and contain a quarter of the carbon (C) stored in terrestrial ecosystems. A disproportionally large amount of the C is stored in belowground biomass and in the soil (> 75 %). The size of the Boreal forest and the large amounts of C stored in the soil make the Boreal forests a key biome to understand in relation to the predicted climate warming. Most current simulation models used to predict the likely effects of climatic change do not include the special features of Boreal forest ecosystems and are based on the commonly accepted dogma that production is constrained by air temperature and the short growing season. These models predict that the projected rise in temperature, in combination with increased CO_2 concentration the atmosphere [CO_2], will increase the production in the Boreal region. Some models, however, predict that increased temperature will drastically increase soil respiration so that forests that today are C sinks will become C sources in the foreseeable future.

The upper limit for forest biomass production on a particular site is set by the amount of incoming radiation during the year. Actual production is, however, determined by the amount of radiation intercepted by the canopy during the vegetation period and, to a lesser extent, by the efficiency of conversion of intercepted radiation into biomass. It is, however, clear from long-term forest experiments, that rates of biomass production in most forest ecosystems are far below their potential level and that increased availability of nutrients (mainly nitrogen) can result in drastic increases in yield.

In the latter part of the 1980's, a nutrient optimization experiment was established in a young stand of Norway spruce in northern Sweden (Flakaliden). The principal aim of the experiment was to demonstrate the potential yield of Norway spruce, under given climatic conditions and non-limiting soil water, by optimizing the nutritional status of the stands.

There has been a spectacular response to the optimized fertilization, with more than a fourfold increase of annual volume growth, indicating that air temperature is not the major direct constraint on tree growth at these latitudes. Temperature may, however, be influencing tree growth indirectly through effects on timing of soil thaw and mineralization of soil organic matter. Thus year to year variability in temperature may influence wood production indirectly through the availability of nutrients and length of growing season.

Results from the long-term manipulation experiments of nutrient availability, air and soil temperature, and [CO_2], will be presented. Our results contradict the generally accepted hypothesis that low temperature is the primary controlling variable of tree growth in Boreal forests, or that increased temperature will drastically increase the loss of stored soil C.

THE LONG-TERM SUPPLY OF BASE CATIONS IN SWEDISH FORESTS: EVALUATING MODELS WITH EMPIRICAL DATA

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Base cations are important macronutrients and essential for buffering soil and water acidity in terrestrial and stream ecosystems. Soil reservoirs of exchangeable base cations, however, may be declining in Europe, eastern North America, and other regions of the world following historical or current atmospheric deposition of sulfur and nitrogen anions, and also from forest management practices. Forests play an important role in mitigating climate change through carbon sequestration and fossil fuel substitution, but intensive forestry operations can remove large quantities of base cations from the soil. This raises questions regarding the long-term supply of base cations in the soil and the consequences of changing base cation availability for future forest production. This study uses annual exports of Ca, Mg, K, and Na from 60 forested catchments in Sweden between 1985 and 2010 and modeled estimates of weathering inputs to evaluate the long-term supply of base cations in Swedish forests.

LONG-TERM EFFECTS OF SITE PREPARATION ON SOIL QUALITY AT HIGH ELEVATION BOREAL FOREST

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Introduction

Soil nutrient losses in intensively managed boreal forests are both ecological and economical concern. In boreal forests mechanical site preparation (MSP) is a common practice to establish conifer plantations after clearcutting, yet little attention has been paid to long-term effects on soil chemical condition. The aim of MSP is to improve establishment and survival of tree saplings mainly by promoting short-term soil drainage and nutrient availability and by reducing competing vegetation. Clearcutting results nutrient losses by biomass removal and leaching, particularly in soil organic C, N, and P, and exchangeable Ca and Mg. Subsequent MSP enhances the leaching.

Material and methods

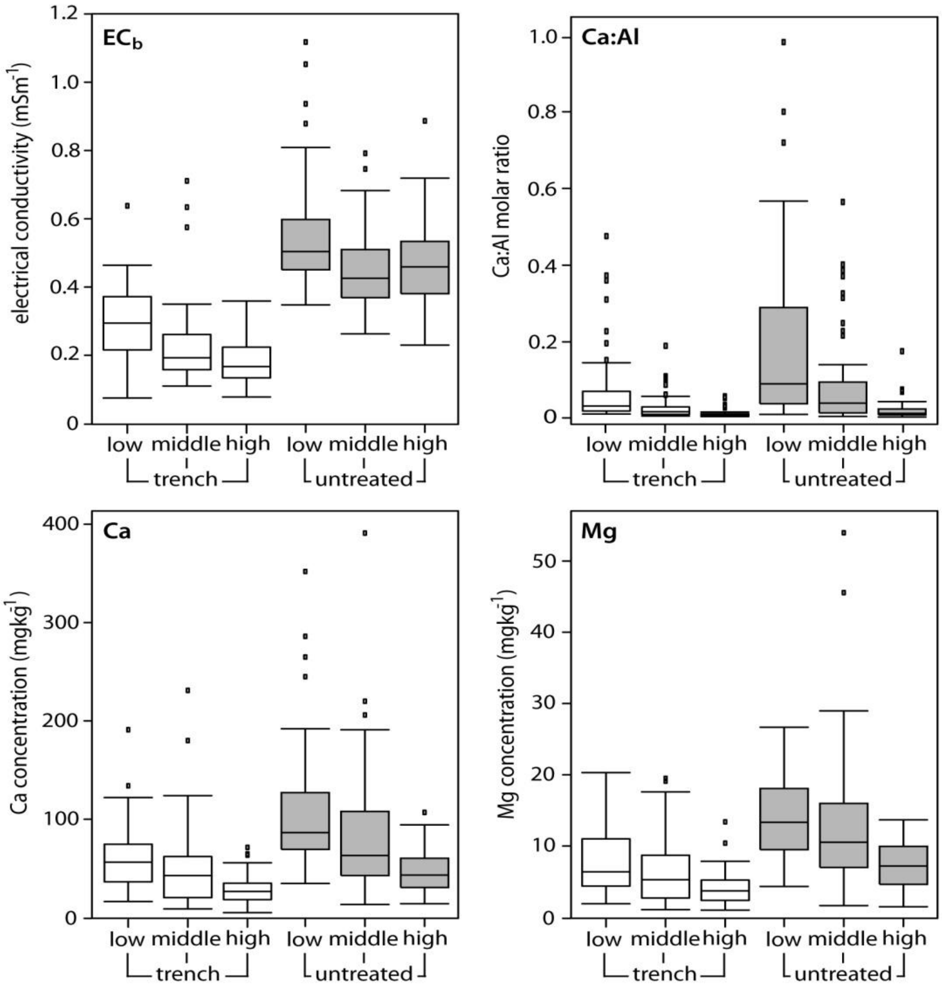
The Tuntsa study site in Finnish Lapland (67°37'N, 29°55'E) has been originally dominated by Norway spruce (*Picea abies*). In 1960, a large-scale forest fire burned the area. Burned trees were harvested, soil was mechanically prepared with continuous cross-contour disturbance tracks, and Scots pine (*Pinus sylvestris*) were planted. The artificial regeneration has failed such that high elevations have remained treeless through 46 years since the forest fire. Also natural regeneration of Norway spruce failed in high elevations.

We established trench (disturbance track) and untreated (between the tracks) microsite pairs to 385, 400, and 420 m a.s.l., 50 pairs at each elevation. At each microsite, soil electrical conductivity (EC_b), as a measure of soil nutrient potential, was measured and mineral soil was sampled. The samples were extracted with ammonium acetate and element concentrations were analyzed using ICP-AES. Differences in soil variables between trench and untreated microsites were analyzed by Wilcoxon signed rank test.

Results and discussion

The MSP has a long-term degradation effect on soil quality, such that soil EC_b has decreased from 0.34 mS m^{-1} in untreated sites to 0.16 mS m^{-1} in trenches. The results agree to observations by Sutinen *et al.* [1, 2] that MSP causes a long-term degradation on soil EC_b in former Norway spruce sites in Finnish Lapland. The EC_b correlates with many soil variables, most notable being Ca and Mg concentration [3, 4]. The Ca concentration has decreased 40 % from 62 to 37 mg kg^{-1}, and Mg concentration 51 % from 9.9 to 4.8 mg kg^{-1}. Furthermore, in trenches acetate extractable concentrations of soil Mn (+72%), Ba (+34 %), and Cu (+25 %) were elevated compared to untreated sites. The molar Ca:Al ratio in untreated sites the ratio was only 0.035, and decreased 57 % to 0.015 in trenches. In high elevation trenches/untreated sites the ratios were 71/85 % lower compared to low elevation due to high Al concentrations.

The elements that decreased in consequence of the MSP had low concentrations in high elevation microsites. In high elevation trenches/untreated sites the acetate extractable concentrations of soil Ca (-53/-51 %), Mg (-42/-46 %), and Sr (-46/-36 %) were lower compared to low elevation, whereas concentrations of soil Na (+150/+109 %), Al (+63/+101 %), Ti (+58/+60 %), S (+54/+76 %), and Cu (+43/+159 %) were higher. The elements that varied in elevation gradient were the same in trenches and untreated sites, and magnitude of the change was generally equal. However, in trenches the soil EC_b decreased 43 % from low to high elevation, whereas in untreated sites the change was minor, which demonstrates that the MSP contributes to leaching also along the elevation gradient.



Boxplots to soil electrical conductivity (EC_b; mS m^{-1}), Ca:Al ratio, and concentrations of Ca and Mg (mg kg^{-1}) in low, middle, and high elevations of trench and untreated sites.

The forest fire and removal of trees has increased wind speeds and thin down winter snowpacks on windblown high elevation areas [5]. The considerable depletion of soil nutrients, particularly Ca and Mg, together with changed wind climate in high elevation area, have caused a long-term failure of both artificial and natural regeneration of spruce and pine. The results indicate that intensive MSP is a risk for watershed chemistry and long-term productivity in boreal conifer forests.

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EFFECT OF THINNING INTENSITY ON BIOMASS PRODUCTION AND ECONOMY OF GROWING BETULA PUBESCENS STANDS ON PEATLAND IN NORTHERN FINLAND

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Introduction

Downy birch (*Betula pubescens* Ehrh.) stands represent a common and typical low budget forestry regime in Northern and Western Finland. On peatlands and wet mineral soils, downy birch is often the first pioneer species to appear after drainage. Downy birch stands can also result from a failed regeneration operation or overdue tending treatment. The regeneration of downy birch is cheap, but traditional silviculture with tending and thinnings is expensive in high density stands. Furthermore, the economic value of downy birch is not very high due to its lower growth capacity and stem quality compared to Scots pine, Norway spruce and silver birch. The growth and management of downy birch stands can, however, be an important topic in boreal forests from the viewpoint of global warming, carbon sequestration and energy wood production. Control of stand density by thinnings has been a major tool in increasing individual tree growth and improving stem quality. The growth response in downy birch stands on peatland sites after thinning and saw timber production has nonetheless been low [1, 2].

The objective of this study was to relate thinning intensity with height and diameter development as well as stem volume and biomass increment. Also, the economic aspects of management patterns were studied both in pulp and energy wood production as well as in integrated pulp and energy production. Besides wood production, the results are likewise of value in carbon balance studies.

Methodology

The study was based on 19 experiments on drained peatland in Ostrobothnia and Western Lapland by the Finnish Forest Research Institute. The experimental design consisted of 2−3 repetitions of heavy (650 − 1 000 stems ha^{-1}), moderate (1 100 − 1 500 stems ha^{-1}), light (1 700 −2 500 stems^{-1}) and very light thinning, as well as unthinned plots. The area of a rectangular plot ranged from 800 to 1 400 m^2. The differences among the treatments were analyzed separately for SS, FW and PW using covariance analysis including the random effect of stand (Mixed linear procedure of SPSS).

Nine experiments (110 plots) were established at the seedling stand stage (SS) with 15 000−40 000 stems ha^{-1} on control plots and 5 000−7 000 stems ha^{-1} on very lightly thinned plots. Seven experiments (82 plots) were started at the fuel wood thinning stage at mean height 8−12 m (FW) with 4 000−10 000 stems ha^{-1} on control plots and 2 500−3 000 stems ha^{-1} on very lightly thinned plots. Three experiments (54 plots) were established at the traditional pulpwood thinning stage (PW) with 2 000−2 500 stems ha^{-1} on control plots. The experiments were studied at 5-year intervals for 20−30 years approaching maturity. Thus, in the study it was possible to monitor the thinning removals, mortality and total stem volume and biomass production during the entire stand rotation (except for SS). Total biomass of growing stock and removal in downy birch stands were studied based on separate components [3]: stem wood, stem bark, living branches, dead branches, leaves, stump and roots (excluding diameter < 1 cm).

Results

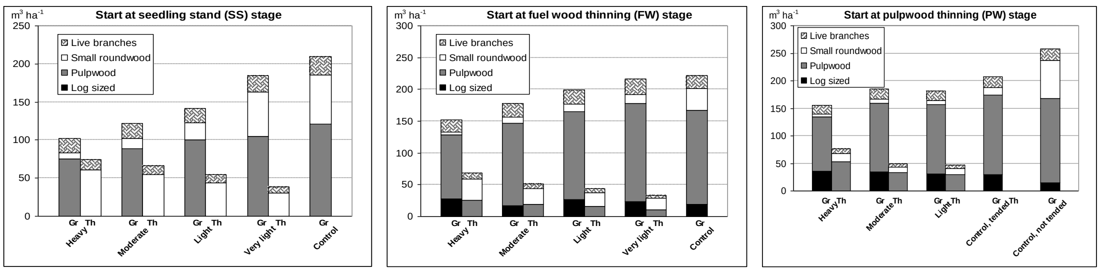
Diameter growth of birches increased with increasing thinning intensity during the first 15 years after thinning at all tree initial height classes (SS, FW, PW), but later in young stands for SS only. However, the mean stem volume of the 600 largest trees ha^{-1} in heavily thinned plots was only 20-30 % higher compared to unthinned control plots after the 25-year study period. Thinning intensity had no influence on height growth. Mortality during the study period was 30-45 m^3 ha^{-1}. Mean stem number of unthinned birch thickets declined from 25 000 ha^{-1} at dominant height 7 m to 3 000 ha^{-1} at height 18 m.

Stem volume growth during the first 15 years was highest (5-6 m^3 ha^{-1} yr^{-1}) on the very lightly thinned or unthinned plots, but later no significant difference existed between the initial thinning intensities. The maximum above-ground leafless biomass (over 100 t ha^{-1}) was achieved on very lightly thinned plots. Also, the total production (including thinning removal) of biomass and stem wood and even the production of merchantable stem wood increased with increasing stand density and they were all highest on very lightly thinned or unthinned plots (figure). During the 50-year rotation, the highest total biomass production was 3.7 t ha^{-1} yr^{-1}. Respective leafless above-ground biomass production of live trees was 2.5 t ha^{-1} yr^{-1}. Accordingly, the highest mean annual production of merchantable stem wood (d >6,5 cm) was 3.6 m^3 ha^{-1} yr^{-1}.

The NPV values of different management patterns were calculated from outturns on road side and from costs of pre-commercial and commercial thinning as well as clearcutting with optimal rotation and harvesting technique. Both pulpwood cutting by a single grip harvester and whole-tree or integrated harvesting by a multi grip harvester were used in thinnings and final cuttings. The optimal management pattern was chosen for each plot using an interest level of 3 % and price-relation 1 / 0.75 for pulpwood / energy wood on road side.

Neither pre-commercial nor commercial energy wood thinning is economically feasible in downy birch stands on peatland. However, at the start of the PW stage, traditional first thinning as a pulpwood cutting did not decrease the economical outturn with an optimal rotation age of 61−64 years. Whole-tree harvesting was used mostly in thinnings at the start of the FW stage and integrated harvesting in clear cuts with an optimal rotation age of 40−50 years. Whole-tree harvesting for energy wood was not a feasible thinning operation at mean height of 8−12 m, but it was cheaper than an earlier pre-commercial thinning.

The optimal rotation was not reached within 20-25 years after pre-commercial thinning in experiments started at the SS stage. It seems that increasing stem sizes and decreasing harvesting costs in the future will not compensate for the cost of pre-commercial thinning in birch thickets. An earlier pre-commercial thinning at 2-3 m height would diminish the costs, but also probably lead to an even denser stand than before due to fast growing sprouts. From the viewpoint of short-rotation management, an initial density of 7 000−10 000 stems ha^{-1} seems to be a better option than much denser stands. The rotation should exceed 30 years when a multi grip harvester is used in the final cutting.



The influence of initial thinning density on the timber assortments in thinning outturn (Th) and growing stock (Gr) at the end of the study period.

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THINNING IN CENTRAL NORWAY. RESULTS BASED ON LONG-TERM TRIALS

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Removal of up to 40-50 % of the total volume production by successive thinning from early age seems to have a positive effect on the yield of fresh wood in stands of Norway spruce. In young stands there is a decrease of yield caused by early, heavy thinning. The stands are usually stable and healthy. Low oriented and moderate thinning operations do not appear to influence the yield situation in general, although culmination is prolonged. Also in Central Norway difficult access to the forests, lack of roads, high labour costs and sometimes low initial densities moderate the present interest for thinning.

PINUS SYLVESTRIS STANDS INFESTED BY GREMMENIELLA ABIETINA – SILVICULTURAL IMPLICATIONS

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The fungus *Gremmeniella abietina* (Lagerb.) Morelet is known to infest and cause damage (Scleroderris-canker) to e.g. Scots pine (*Pinus sylvestris* L.) [1, 2]. In the year 2000, large areas of forests in Sweden were infested by the fungus. Almost 500 000 hectares, mainly 30–50 year old trees, had been infested during 2001–2003 [5], the largest-ever documented outbreak in Sweden. An infestation results in defoliation of varying severity and may even cause tree death.

Outbreaks of *G. abietina* have occurred regularly in Sweden. In the future, outbreaks are still likely, but possibly less frequently according to Sonesson et al. [4]. *G. abietina* infestation is promoted by rainy, cool and cloudy weather in the summer [1], and climate scenarios predict increased frequency of warm and sunny summers [4]. Nevertheless, there is a need for knowledge on whether an infested stand should be left untreated or whether a sanitary cut should be undertaken, either in the form of thinning or as a final cut.

The aims of this study were to investigate: (i) the relationship between *G. abietina*-induced tree crown transparency (CT) and Scots pine tree mortality; (ii) the influence of CT levels on stem growth; (iii) the recovery of the crown; and (iv) the association of CT levels and colonization by *T. piniperda*. Improved knowledge on these issues is needed for developing guidelines on how to manage infested stands.

After the outbreak in 2000, permanent study plots were established in five stands infested by *G. abietina* and four in reference stands, not obviously affected by the fungus. The plots have been recurrently assessed during a five-year period after the *G. abietina* attack regarding CT, tree mortality, tree growth, and colonization by *Tomicus piniperda*.

The tree mortality and *T. piniperda* colonization one year after infestation have been reported in [3]. In the current presentation the development, during five years, of CT, as well as, tree mortality and tree growth, both for individual trees and on an area basis, will be reported. Predictive functions for the probability of mortality for trees with G. abietina-induced CT were determined. Furthermore, the occurrence of colonization by *T. piniperda* on stems of Scots pine trees depending on CT will be presented. Based on these results some practical silvicultural measures to be undertaken in infested stands will be suggested.

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COST EFFICIENT REGENERATION AND YOUNG STAND TREATMENT - CHALLENGES AND POSSIBILITIES

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Many forest owners live in towns, are less dependent on forest income and have multiple values in forest management. Earlier the management practices were less or more determined. Now the role of researchers and practical foresters is more interactive. They provide information on different alternatives and their consequences, and the forest owner makes the final decisions after his values and objectives.

Stand management is a unity, where every action effects on the following actions. Earlier silviculture and harvesting were separated and mostly examined as individual operations. To find the best economic result, all aspects influencing costs, quality and timing of silvicultural and harvesting operations as well as wood production and quality must be taken into account. Challenges and possibilities in regeneration and young stand management are discussed in this presentation.

Beginning of the rotation period is conclusive and failures in that period are hard to repair. First example compares alternative Norway spruce regeneration chains and the role of soil preparation. Stand development as well as conditions and costs of cleaning and young stand management after soil preparation methods (disc trenching/spot mounding) are compared. When costs and income for forest owner are compared at the first commercial thinning stage, the cheaper soil preparation using disc trenching gives poorer economy.

Mechanization of silvicultural operations is a must. Compared with harvesting the mechanization in silviculture is only just starting. Lack of labour and costs pressure are the key drivers in mechanization. There are many promising solutions for mechanized planting, cleaning and pre-commercial thinning operations. Even here the cheapest method in not always the most costs effective in the longer run.

Energy wood has a high political and social status. Energy wood procurement has various connections to silviculture and forest management. Harvesting of stumps has increased rapidly, but our knowledge on silvicultural and ecological aspects is deficient. In Finland energy wood harvesting is promoted with state subsidies in dense young stands, where young stand treatment has been neglected. In these stands harvesting costs is high and silvicultural harvesting quality is often poor. A more reasonable way is to include energy wood in forest management schedule, which way is discussed in presentation.

For comparison of management practices stand simulators are excellent tools. Motti stand simulator developed at Finnish Forest Research Institute gives possibilities to compare the total picture of different management practices. When you know the consequences, you can make your decisions.

CONTRASTING POLICY TARGETS? - EVALUATION OF POLICY INSTRUMENTS AND CERTIFICATION SCHEMES IN NORWEGIAN FORESTRY

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The Government of Norway has stated that they will increase the level of harvesting in general, and also increase the production of bioenergy based on woody biomass [1, 2]. At the same time there is a high focus on maintaining biodiversity [3]. One way of combing these two targets are through implementing measures for maintaining biodiversity into all forest management. This is ensured through certification schemes and through legal statues. All in all there exist a wide number of instruments aimed at securing an ecologic and social sustainable forest management. Earlier studies on the effects of environmental constraints on available woody biomass or economic have mostly been based on rather rough estimates [4]. Given the ambitious political targets it seemed necessary to investigate the actual effect of all the environmental constraints affecting forestry today. We have performed a study aiming at describing the effect of environmental constraints on the area of productive forest available for forestry, and on the effect on growing stock that can be harvested. All constraints are analyzed according individually, and considering overlap with other constraints. The analysis is based primarily on data from the National Forest Inventory.

In total, approximately 28% of the productive forest area in Norway is restricted in different degrees. We have separated the productive forest into Forest Management Alternatives (FMA). *Conservation* (FMA1) through Nature Reserves and National Parks alone cover 2.3 % of the productive forest. *Area Protection* (FMA2) through key habitats (MiS-figures), buffer zones and protected landscape areas and habitat protection areas cover additionally 10.9 % of the productive forest. Forest areas with a *Combined Objective Forestry* (FMA3; social forestry/multiple use) such as urban forests and mountainous forest cover 13.2 % of the productive forest. This leaves slightly above 70 % of the productive forest left for *Production Forestry* (FMA4). However, also in the production forest there are restrictions on the available volume for harvesting, as measures such as protecting game habitats, recreational areas, and cultural heritage are taken. In total > 20 % of the standing volume cannot be harvested due to environmental restrictions [5].
A cost-supply analysis revealed that the main source for increased biomass extraction in Norway need to be the productive forest where there is a substantial potential for utilization of harvest residues [6]. Thus, the high level of environmental constraint on the area and volume accessible for harvesting might lead to difficulties in reaching the political ambitions of increased harvesting levels in future.

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SOIL CHEMISTRY CONTRIBUTES TO ALPINE SPRUCE TREELINE IN FINNISH LAPLAND

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Introduction

Soil properties tend to be associated with the underlying rock types [1], yet those also exhibit variations with respect to elevation. This concept of vertical soil zonality, first introduced by the Russian soil scientist Dokuchaev in the late 1890's, implies that soil nutrient content tends to decrease along with increasing elevation [2]. This feature will eventually restrict the spread of spruce [3], known to be particularly tied to elevated concentrations of soil Ca and Mg onto higher fell elevations [4]. The soil zonality hypothesis has not been tested along forest-tundra gradient of Fennoscandian mafic fells.

Materials and methods

The 557-m-high Palaeoproterozoic Lommoltunturi fell (mountain shaped by Pleistocene glaciations; centered at 67°59′48′′N and 24°09′30′′E) is composed of mafic Mg -tholeitic metavolcanite rocks, and covered by a thin veneer of glacial till. The soil types range from Typic Haplocryod to Skeletic Podzol in the forest-transition to Skeletic Leptosol in the tundra. Lommoltunturi fell is a part of the Pallas-Ounastunturi National Park, where Norway spruce treeline reaches 530-548 m on the mafic fells, whereas spruce is absent in the northern part of the due to nutrient-poor soils derived from felsic granitoids [4].

A total of 46 plots, 10x10 m in size and with 50-m-spacings along three transects, were established on the west slope of the Lommoltunturi fell. At each site, soil electrical conductivity (EC) soil water content. Mineral soil (0-10 cm depth) was sampled for pH and for concentrations of soil elements extractable with 1 M ammonium acetate at pH 4.5 using ICP-AES. Total carbon and nitrogen were analyzed on a dry-weigh percent basis. At each site, the age (dendro-laboratory) and height (in field) of spruce individuals were determined.

Results and discussion

The soil EC, Ca:Al ratio, and concentrations of the soil Mg and Na were higher in forest, whereas concentrations of the soil Al and total N were higher in tundra (Kruskal-Wallis test $p \leq 0.01$). With regard to soil chemical properties the transition zone was intermediate, except for concentration of the soil total N, which was lower both in forest and transition zone compared to tundra. The soil variables, correlative with elevation ($p \leq 0.01$) were as follows: EC ($r_s = -0.58$), soil water content ($r_s = 0.43$), Ca:Al ratio ($r_s = -0.46$), Al ($r_s = 0.58$), Mg ($r_s = -0.39$), total N ($r_s = 0.49$), S ($r_s = 0.39$).

Our data on soil zonality suggest that possible constraint for spruce in tundra is low Ca:Al ratio [5]. Even in the forest, Ca:Al ratio of 0.23 (median) pose a considerable Al-stress for spruce. The maximum concentrations of the soil Mg and Ca, and the soil Ca:Al ratio of 2.2 was found at 420 m a.s.l, where the pioneer establishment of Norway spruce occurred in 1840's and 1860's (Fig. 1; [6]).

The age structure of Norway spruce along the altitude gradient demonstrates an upward shift onto higher elevations (Fig. 1, [6]). The oldest spruce was only 165 years of age at 418 m a.s.l. and was 15.1 m high. The tallest spruce, 19.5 m, was also at 418 m and yielded the age of 144 years. Beyond the transition zone, i.e. the range from 475 to 505 m a.s.l., the spruce individuals were less than 22 years of age.

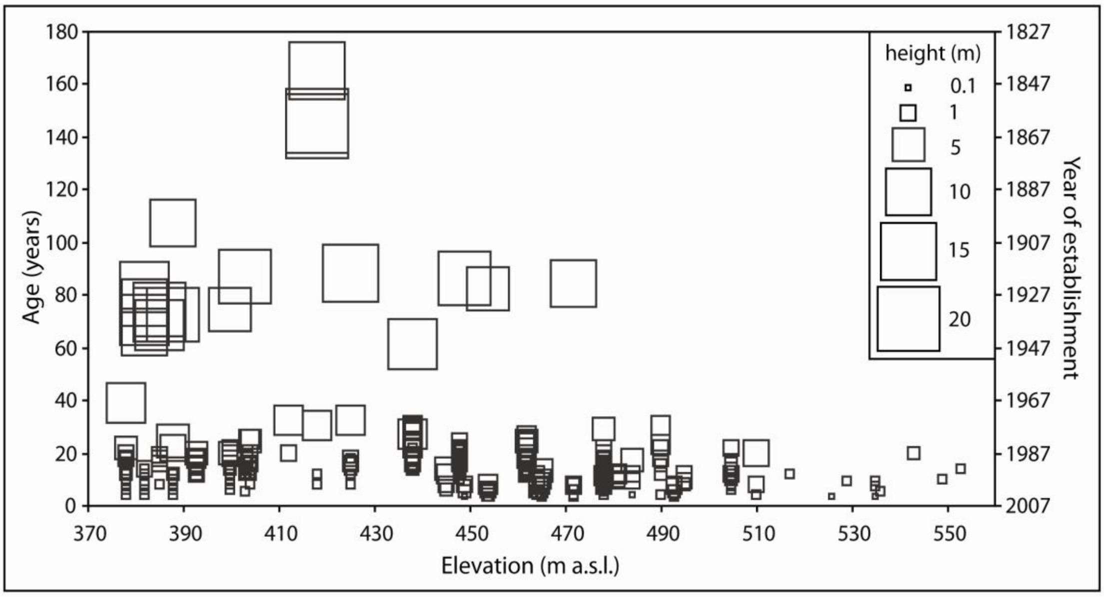

Figure 1. The age structure of *Picea abies* along the Lommoltunturi fell gradients, Finnish Lapland. Height is described by the size of the squares.

We found soils to be zonal, such that the concentrations of soil Ca and Mg decreased, while Al increased along with increasing elevation. Spruce had first established, in the 1840's and 1860's, at 420 m elevation with highest concentrations of the soil Mg and Ca, and the soil Ca:Al ratio. During the climatic warming in the 1920's the spruce forest line shifted to 472 m and it took 60 years to shift the line by 55 m in elevation. Low soil Ca:Al ratio of 0.02 in tundra is considered to be constraining in tundra [5, 6, 7]. No evidence of fire disturbances or evidence of old stumps/megafossil logs was found, hence we argue that the Norway spruce has expanded onto formerly tree-free Lommoltunturi fell, Finnish Lapland.

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FORESTRY, BIODIVERSITY AND ECOSYSTEM SERVICES: CRITICAL ISSUES AND RELEVANT POLICIES

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In addition to timber and pulp wood, the boreal forest supplies a range of other ecosystem services, such as climate regulation, erosion protection, fresh water and cultural benefits. Boreal forest is also the source of a rich diversity of species. In recent years there has been much focus on the relationship between forestry production, biodiversity, and ecosystem services for climate control in boreal forests. This keynote speech addresses how these concerns can be seen in context, and what principles should apply to trade-offs between them. Further, it discusses some of the biodiversity means taken in today's boreal forest, based in legislation or in forest certification schemes - such as the long-term retention of forest structures and organisms. What do we know about the effects of these environmental measures on forest biodiversity? And how can we implement an integrated forest management with a sound balance between different objectives in boreal forest?

REDUCING CONFLICTS IN THE USE OF NATURAL RESOURCES: FROM FACTS TO FRAMES

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Conflicts and disputes over natural resources are becoming more frequent due to increasing populations, differing value systems, and greater economic and environmental demands on finite resources [2]. In northern Europe, disputes arise mainly because of the increase in building, recreational use, mining, road and route construction, and other, often new kinds of land-use pressures. Some forms of land-use are mutually exclusive; others can be committed in the same areas. However, in any case, negotiations between stakeholders are needed even though it is not always clear who the stakeholders are. In addition, it is not always self-evident that conflicts are negative.

The reasons and explanations for the emergence of incompatibility in land-use can be divided into five categories: interests, facts, values, argumentation and process [3]. In this presentation, I will first unpack these categories and then discuss what the possibilities of research are to prevent and to reconcile conflicting situations. Two empirical examples referred to in this presentation come from northern Finland. The first one is the dispute between forestry and reindeer herding in Inari municipality in northernmost Lapland, and the second is the forest dispute in Muonio, northwest Lapland, which occurred between tourism and forestry.

Many of the environmental conflicts can be defined as 'wicked problems' in the sense that they involve multiple stakeholders and multiple issues, include few fixed points onto which a resolution of the conflict could be built and are based on fundamental differences in values and principles [4, 6].

It is common to refer to collaboration and learning process as a solution to problematic situations. The traditional role of research in this process would be to give the 'facts', i.e. to collect, create and offer all the knowledge needed. However, what is also of extreme importance is how the situation is defined and 'framed'. Framing affects the manner conflict is perceived [7], and it directs attention to those facts that are regarded as relevant in the situation in question. The better the problem is defined the shorter time the solution finding takes. In this process social sciences could be of help in analyzing the ways different stakeholders understand the problem, which is essential to effective dialogue [1].

Benign idea of the best argument winning does not hold in many cases. Complex conflict situations may never be 'resolved', and an agreement is reached to put an end to those incompatibilities that caused the conflict. Rather, many complex conflicts can be managed well, so that the conflict situation, and the specific disputes that arise within them, do not become destructive [3, 5].

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TOWARDS COMBINING FORESTRY AND TOURISM IN FINLAND: FOREST LANDSCAPE PREFERENCES OF INTERNATIONAL TOURISTS IN NORTHERN FINLAND

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Introduction

In many rural regions in Finland the key development areas are forestry and tourism. In rural areas forestry as a large industry has significant impact on the quality of landscapes for nature tourism. Commercial forests for timber production are increasingly important to tourism activities in addition to the nature protection areas. Tourists mainly evaluate the environment in terms of landscape, where attractive scenery becomes one of the most important reasons for the choice of destination. Previous research suggests that tourists prefer mature forest stands, and their attitudes are negative towards final harvesting, in particular towards clear cutting, which is a widely used method in commercial forests [1, 2]. Although there are many studies about the landscape preferences of Finnish people [3, 4], preference studies among foreign tourists are sparse. Therefore, synergies and conflicts between forestry and tourism need to be studied comprehensively, and the main focus should be on foreign tourists. The aim of this study was to find out what kind of forests foreign tourists visiting Finnish Lapland consider to be suitable tourism environments and what demographics and expectations associated with the tourism destination could explain the rankings.

Materials and methods

We made a survey studying foreign visitors' attitudes towards different forest management practises on landscapes. The data consisted of 750 interviews conducted in Finnish Lapland during the years 2007-2008. There were three interview periods: in the middle of winter, in the late winter and in the summer. The places selected for the interviews were e.g. airports and tourism centres. The sampling of the tourists could be considered as random sampling on the sites where 451 respondents were asked to assess 28 forest landscapes in the summertime, and 299 respondents the corresponding landscapes in the wintertime using colour photographs (a continuous scale from 0 to 10). In addition, the respondents were asked about their demographics and the importance of different characteristics involved in their tourism destination (a scale from 1 to 5). Thus, it was possible to compare the rankings of similar landscapes in their summer and winter appearances.

In addition to frequencies and cross-tabulations with chi-squared tests and log-linear models, factor analysis (principal axis factoring with Promax rotation) and Cronbah's alphas were used in the grouping of the single landscape pictures into larger landscape categories for further analysis. The 19 items describing the importance of features in the tourism destination were grouped respectively. The sum variables (means of the original variables) were calculated to represent the item group. Furthermore, the respondents were grouped using k-means cluster analysis into three landscape preference groups based on their rankings of the landscape categories. Finally, Conditional Recursive Partitioning Trees [5] were used to find the relations between the Landscape preference groups, demographics and the desirable features in the tourism destination. The tree analysis and the factor analysis for landscape pictures were done separately for summer and winter pictures. The results of Conditional Partitionings were controlled by using cross-tabulations and ordered multinomial logistic regression models. The analyses were done mostly using an R statistical environment (version 2.11) [6].

Results

Winter landscapes compared to corresponding summer ones
Four landscape categories (with mean scores of summer/winter landscapes) could be distinguished: 1) regeneration area (summer 3.8/winter 6.0), 2) dense forest, age varies (7.4/7.1), 3) spacious view, big trees (6.7/8.8) and 4) half open area, sparse trees (5.5/7.2). The respondents appreciated winter landscapes more than the corresponding summer landscapes. In addition, the variation in the rankings of winter landscapes was smaller compared to the summer ones. Regeneration areas were the most unsatisfactory environments, but they looked considerably better in the wintertime. Dense forests as well as spacious forests dominated with big trees were considered as the most preferable environments.

Landscape preference typology groups
The respondents were divided into three landscape preference typologies using k-means cluster analysis in the summer landscape data: 1) negative, 2) medium and 3) positive persons based on their rankings of the four landscape categories. Meanwhile, the typologies of negative and positive were distinguished in in the winter landscape data.

The factors related to the preference typology groups
Residential environment (large city, small city, town or countryside), region of living (5 regions), the importance of nature surrounding the tourism destination explained respondents' preference typology among the rankers of the summer landscapes. Interestingly, a respondent's increased appreciation of nature increased his or her probability to belong to the positive typology group. The effect of the region on the rankings of the summer landscapes varies depending on the other explanatory variables. Among the rankers of winter landscapes, only a respondent's residential environment and the importance of nature were related to the typology group. Furthermore, increasing nature orientation increased a respondent's probability to belong to the positive typology group also in the winter landscape data.

Discussion and conclusions

The results suggested that commercial forests may be admissible in tourism environments, especially for nature-oriented tourists. Foreign tourists are even more permissive towards forest management than the domestic ones are [1]. However, big differences between the tourists were found, especially in the rankings of the summer landscapes. A person's cultural background and expectations understandably have a remarkable effect on his or her landscape experiences. The complex relationships between demographics, expectation, motives and landscape preferences should be studied more closely in the future.

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THE EFFECT OF INTENSIVE FERTILIZATION ON HEIGHT DEVELOPMENT IN YOUNG UNTHINNED SCOTS PINE (PINUS SYLVESTRIS L.) STANDS

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Demands for forest biomass, mainly for use as biofuels and energy generation, have been rising for several years. Growth of trees are affected by environmental factors. For example, competition for light affects the allocation of growth along the stem, and competition for water and / or nutrients affects the overall growth rate [1, 2, 3, 4]. However, few studies have been investigating the effect of intensive fertilization on height development in young unthinned stands. Therefore the aim of this study was to determine the principal effect of fertilization on height development in young Scots pine trees (*Pinus sylvestris* L.). The hypothesis being that Scots pine trees from intensively fertilized unthinned stands have a higher both absolute and relative hight development than trees from unfertilized unthinned stands.

Within this study, in all 101 trees from three field trials in Northern Sweden, investigating fertilization and spacing in young Scots pine dominated stands, were felled and measured. 68 trees from the unthinned treatment and 33 trees from the unthinned intensively fertilized treatment (100 kg ha^{-1} annually from 1997 onwards). Total height in spring 2009 and annual height growth (top shoot) for the years between 1999 and 2008 were measured with measuring tape. All investigated trees were within the same range of height in year 1999. Differences regarding total height year 2008, mean height year 1999 and annual height growth for years 2000-2008 were analyzed with standard GLM procedure. Used model was ”site” and ”treatment”.

Significantly higher total height increment was found for the intensively fertilized treatment during the investigated period. Fertilized trees had a 3 % higher mean height (5.3 m) than unfertilized trees (5.2 m) at the start in the year 1999. After the growing season year 2008 fertilized trees mean height (9.45 m) was 12 % higher than unfertilized trees (8.53 m).Generally during the period, the fertilized trees expressed both higher total and relative annual height increment than the control (Fig. 1).

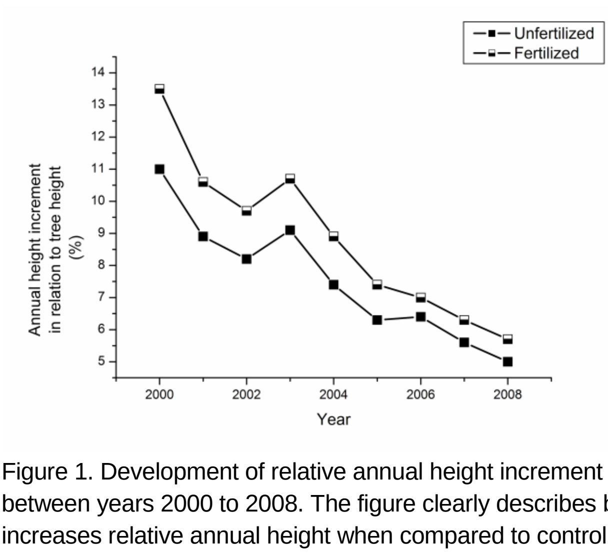

Figure 1. Development of relative annual height increment for unfertilized and intensively fertilized sites between years 2000 to 2008. The figure clearly describes both the overall trends that fertilization generally increases relative annual height when compared to control and that the difference in relative increment is higher during the first years of intensive fertilization than later in the cycle.

Fertilized trees showed significantly higher relative height increment during all years except for the last year 2008 when the relative increment was the same as for unfertilized trees. Note that the fertilized trees then was significantly higher than unfertilized trees. In absolute values differences between treatments regarding height increment varied between 17 % and 28 %. Site had significant effect on relative height increment during the years 2000, 2002–2003 and 2005-2006. No apparent trend could be found explaining this when examining individual tree and site variables. However, variable site was not significant during years 2007 and 2008 when also the difference in relative height increment was the smallest.

Total height and relative increment was as described above significantly higher in fertilized trees when compared to unfertilized thus supporting the hypothesis. Both the absolute and relative difference between treatments was largest in the beginning of the studied period and then generally decreased over time. This pattern indicates that the studied net effect of the intensive fertilization on height development is a result of interactions not included in this study. This is interesting and in need of further studies since the literature describing these and other related growth factors in very young dense stands is sparse. The effect of site was significant in only 5 of the 9 years included within the study. Probably will future studies using the combination of this type of data together with information concerning climatic and soil interactions be useful for development of more knowledge regarding tree and stand height development.

Many studies have been investigating height development in young stands in relation to pre-commercial thinning and recent studies include those by [5] and [6]. The general conclusion from these and earlier studies is that the mean height is likely to decline with higher stem densities due to a higher number of suppressed trees in the stand. The results presented here indicates that fertilization is a treatment that increases site index and thus might allow development of silvicultural management schedules that can use higher stem densities without as pronounced negative effects on stand height development.

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5. POSTER PRESENTATIONS

GROWTH REACTIONS AFTER SELECTIVE CUTTING IN NORWAY SPRUCE (PICEA ABIES L. KARST) STANDS

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Four Norway spruce stands treated with single tree selection were studied 11 years after the cuttings. In each of the stands we performed four strengths of cuttings in 0.2 ha plots, with removals ranging from zero to 70 % of the basal area. We investigated accumulated and annual growth, changes in stand structure, tree age and tree damage. 10-20 % of the living trees were still damaged 11 years after the cutting. The diameter distribution displayed a reverse J-curve in all plots both before and after the cuttings. Eleven years later, the curve is only slightly changed. Annual ring widths from 300 increment cores were analysed. Most trees started to increase the growth two or three years after the cutting. This improved growth accelerated the following six or seven years with 20-80 % increase. Both small and large trees reacted, including severely suppressed trees. The initial crown volume and crown vitality after cutting is essential for the increased growth since several years are necessary to build up a larger and better crown. A reduced volume per hectare provided an increased growth for each of the remaining trees and indicates less competition for nutrients and light after cutting. The observed growth during the 11-year post-harvest period was about 10 % less than the estimated yield capacity for even-aged stands.

ESTIMATION OF SITE INDEX IN OLD, SEMI-NATURAL STANDS OF NORWAY SPRUCE AT HIGH ALTITUDE

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Site-index in Norway is given by the dominant height of an even aged stand at reference age 40 years at breast height (1.3 m above ground). The site-index curves which are standard for Norway spruce (*Picea abies* L. Karst.) [2], are suspected to underestimate the site-index in old, semi-natural spruce forests at high altitude characterized by naturally regenerated, uneven-aged stands with low density. The aim of this study was to estimate the accuracy of site-index estimates in such forests and suggest some age corrections by comparing to measures in adjacent cultivated spruce stands.

Along stand boundaries caused by either property boundaries or strip harvestings, we established 17 pairs of field plots in the municipalities of Sør Fron, Ringebu and Øyer. Each pair consisted of one plot in the old, semi-natural stand and one in the adjacent cultivated stand, aiming at least possible difference regarding to altitude, vegetation, topography and soil.

Mean age at breast height of dominant trees varied from 106 to 182 years at semi-natural plots and from 23 to 42 years at the cultivated plots.

The site-index curves of Tveite [2] underestimated the site-index by 4.2 m on average. Site-index estimated by site properties resulted in underestimations of 4.5 m and 3.9 m on average for the equations G10 and G4 respectively [1]. The presented models for age corrections showed that the underestimation increased by age and that dominant height only increased slightly by age. The results also suggest that the deviation of the height-age relation at the semi-natural plots from the site-index curves relates to wind exposure and soil depth. We argue that the underestimation of site index in semi-natural stands is due to a slower and less persevering height growth compared to cultivated stands at similar sites due to differences in density and genetic origin. We suggest applying the presented model 3-alder, which is a linear function of age, for age correction in old, semi-natural spruce stands 50 to 300 m below forest line in Eastern Norway.

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A SURVEY OF NATURAL REGENERATION OF NORWAY SPRUCE ON SCARIFIED CLEAR-CUTS

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In Norway, the use of natural regeneration for reforestation of spruce stands has increased in recent years, but the practical results have been little studied [1]. We carried out a survey of natural regeneration in 99 clear-cut stands of medium site index (G14) within a 35 000 ha forest estate in southeast Norway (Romedal and Stange Commons). The stands were scarified during 2001-2006, usually one or two years post harvest, and the inventory was carried out during June-October 2008. Seedlings were counted in 15 plots per stand, the plot area depending on species and cohort (1 m^2 for one- or two-year old spruce seedlings, and 16 m^2 for pine, broadleaves and spruce older than two years). Here, we focus predominantly on the establishment of spruce seedlings, of which the majority emerged in 2007, following a rich seed year in 2006, i.e. two years prior to the inventory. The influence of site factors was assessed using a generalized linear mixed model approach, which allows accounting for random plot and stand effects.

The time elapsed between scarification and the main seed year in 2006, as well as the vegetation type and location of plots in relation to potential seed bearing trees in adjacent stands were the most important factors affecting spruce seedling establishment (Fig. 1, $p<0.0001$ for all factors). Overall, the density of spruce seedlings was acceptable in stands scarified in 2006, immediately before the rich seed fall. Among stands scarified during 2003-2005, the regeneration result was highly variable. The poorest results were found in stands scarified in 2001 or 2002, where seedling densities of spruce were mostly very low. This can be attributed to the establishment of competing vegetation in the scarified spots, leaving the older ones to be of little value as a germination substrate at the time of seed fall in 2007.

The dominating vegetation types in the inventoried stands were cowberry woodland (n=29), bilberry woodland (n=52), or small fern woodland (n=18). The small fern type contained the highest densities of spruce seedlings, while there was no difference between the other two vegetation types. The difference between vegetation types depended on the year of scarification however, being largest in stands scarified most recently ($p<0.05$ for the interaction).

About twice as many seedlings were present at 10 m distance from a stand edge with potential seed-bearing trees, compared with plots located at 40 m distance from the edge. This illustrates the need to consider also the configuration of the clear-cuts when aiming at natural regeneration of spruce after clear-cutting.

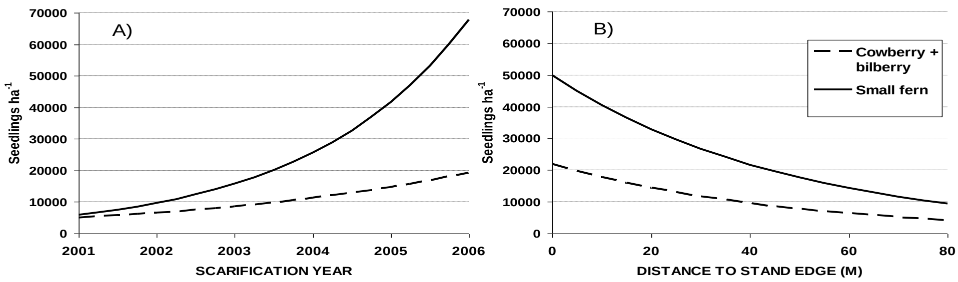

Figure 1. General linear mixed model showing the number of two-year-old spruce seedlings in 2008 as a function of the time elapsed since scarfication (A), distance from the sample plot to the nearest stand edge with potential seed-bearing trees (B) and vegetation type (A, B). There were no significant differences between the cowberry and bilberry vegetation types.

Older spruce seedlings contributed only modestly to the regeneration result, regardless of stand age (median 530 seedlings ha^{-1}). A lack of good seed years during the years 1999 – 2005 may explain this, and a large proportion of the older spruce seedlings had probably established as advance growth. In stands that contained scattered retention trees of Scots pine, establishment of pine contributed significantly to overall seedling densities. However, potential seed trees of pine were often lacking or only present at rather low densities in the harvested stands, so this contribution was usually not sufficient to secure adequate regeneration.

Considering that the main objective in these stands was to obtain a spruce dominated regeneration, the overall regeneration result can only be regarded as satisfactory in the stands that were scarified immediately prior to the 2007 seed fall. A prerequisite for this condition was that the configuration of the clear-cut did not compromise seed supply.

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PINE WEEVILS - A THREAT TO SUCCESSFUL REGENERATION

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Introduction

The pine weevil *(Hylobius abietis)* is an important pest to conifer seedlings in large parts of Europe. Pine weevils migrate to fresh clear-cuts in the spring to oviposit on stump roots. Adult weevils feed on the stem bark of planted conifer seedlings, wounding or killing them. The last years, several severe attacks of pine weevils on forest seedlings have been reported in Norway. To get an objective measure of the extent of damages related to pine weevils in South-Eastern Norway, a survey was implemented in 2010 [1].

Methods

Altogether, 155 regeneration stands in nine counties in SE Norway were examined, most of them during the autumn of 2010. Two of the stands were planted with Scots pine *(Pinus sylvestris)*, the rest with Norway spruce *(Picea abies)*. Planting had taken place during 2009 or 2010, and harvesting had been carried out not more than two seasons before planting. In most of the stands no site preparation had taken place before planting. In each field, all planted seedlings in 20 circular plots of 20 m^2 were examined for pine weevil damages as well as other types of injuries. Field variables like height above sea level, stand size, soil moisture, inclination and seedling type were also registered. To examine whether any of these variables had affected the degree of pine weevil damage, ANOVAs were conducted (GLM, [2]) using the percentage of killed and wounded seedlings as dependent variables.

Results and conclusion

The percentage of seedlings killed from pine weevil attacks varied between 0 and 63 % in the surveyed fields. On average, 7 % of the seedlings were killed by pine weevils, while 23 % had wounds. In addition, 3 % of the seedlings were killed by other causes. There was variation in seedling damage among the different counties (2-18 % of the seedlings killed by pine weevils and 10-40 % wounded).

There was a higher percentage of wounded (31 %) and killed (9 %) seedlings in stands planted two seasons ago compared to one season. It is likely that mortality will increase during 2011 in the stands planted in 2010.

Few of the registered field variables were correlated to the degree of damage, but there was a tendency towards higher mortality at the largest clear cuts, in hilly areas, and for dry soil types. Stands at high altitudes had somewhat lower damages on average, but there were stands with high mortality due to pine weevils also at altitudes of 6-700 m a.s.l. 1-year old container seedlings had higher mortality than 2-year olds. Seedlings treated with the insecticide Merit Forest had lower mortality and fewer attacked seedlings than those treated with Karate Zeon.

The present survey shows that in unscarified stands in SE Norway pine weevils are the most important cause of seedling mortality. A total seedling mortality of at least 10 % should be expected the first two years.

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LAMMAS SHOOTS IN SPRUCE – OCCURRENCE, GENETICS AND CLIMATE EFFETCS

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In the northern hemisphere proper timing of onset and cessation of growth is crucial to avoid injury from late spring frosts and early autumn frosts. Normally Norway spruce (*Picea abies* (L.) Karst.) has one growth flush during the growth season. However, in some cases a second flush is observed in young trees. The shoots resulting from the second flush are called Lammas shoots. Any delay of growth cessation may postpone the onset of hardiness development, and thus make the trees susceptible to frost injury during autumn. It is also possible that the late bud formation will affect the timing of bud burst the following spring, and thus increase the risk of spring frost injury. Frost injuries to the terminal bud can result in two or more lateral branches competing for the lead. It has also been recognized that this second, but short, elongation of the leader cause a higher number of nodal branch buds to form. These later develop into the main branch whorl that in many cases appears as "double".

Increasing occurrence of Lammas shoots has been reported over the last years in Norway. This is possibly an effect of changing climatic conditions. On this background we recently carried out a survey on forest land in lowland of South East Norway[1]. This pilot study showed that Lammas shoots are present with relatively high frequency on the most productive sites (Fig. 1), and that their occurrence increases the probability of development of multiple tops (forking) the following year (Fig. 2). This may influence structural wood quality in a negative way and cause spike knots and double whorls. Thus, the possible increased occurrence of Lammas shoots may be a negative factor in the production of quality timber in the Norwegian forest. Reduced structural strength might also influence on resistance towards wind felling.

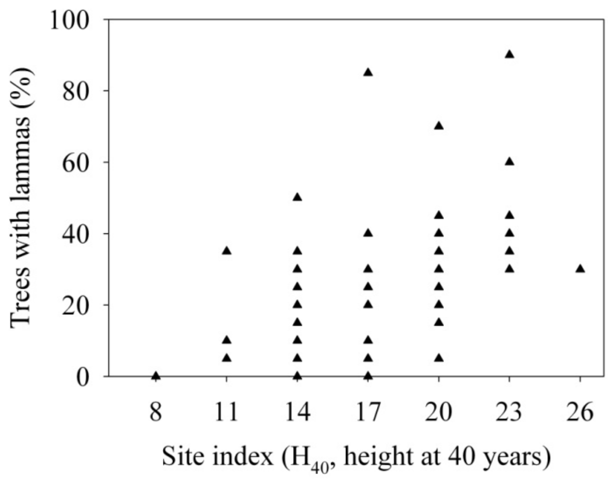

Figure 1. Relationship between site index (H_{40}-system, based on height at 40 years age) and occurrence of Lammas shoots.

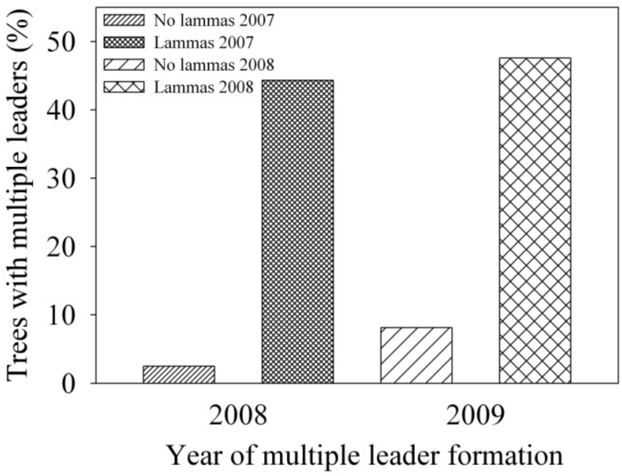

Figure 2. Relationship between Lammas shoots and forking.

Lammas shoots have been observed in genetic experiments with Norway spruce, with substantial differences in occurrence both among and within natural populations (provenances), and among families in breeding populations. In an experimental series with families and clones planted in short term trials and in field trials in Norway, Åland, Finland and Denmark, a considerable variation is present among families in the frequency of Lammas shoots. A strong relationship between formation of Lammas shoots at age five in the short term trial at Ås, Norway, and at age 21 years in the field trial at Paimio, Finland were observed. There is also strong correlation between Lammas occurrence at Paimio at age 21 and timing of bud flush at Ås at age five. Similar results were found in Denmark and Åland.

Further knowledge on Lammas shoot formation and its implications is necessary in order to provide sound recommendations for breeding and silviculture and thereby secure sustainable high quality wood production of Norway spruce under changing climate conditions.

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DECISION SUPPORT MODELS FOR INCREASED HARVEST AND CLIMATE-MOTIVATED FOREST POLICIES

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Background

In Norway, the current carbon sink of the Land Use Land Use Change and Forestry (LULUCF) sector is about 40% of the national carbon emissions. The net carbon uptake is expected to remain high but the future forest carbon sequestration will be affected by both forest management and climate change. It is a political goal to reduce the annual carbon emission by 15-17 million tonnes CO_2 by 2020. The forestry sector is expected to contribute through increased extraction of biomass for bioenergy, extended use of wood in construction and as replacement for energy-demanding products, altered management practices that increase annual increment, and sequestering of atmospheric carbon in the forest area.

Recently, the National Forest Inventory data has been used together with a modified version of a forestry planning tool (Avvirk2000) and a soil carbon model (Yasso) to produce carbon budget scenarios for Norway. These scenarios have generated a vigorous and continuing public debate concerning the role of forests in Norway's climate policy and optimal harvest level in Norwegian forests. A key issue has been the actual effect on carbon emissions and trade-offs between a forest carbon stock and increased harvest to facilitate increased substitution of fossil fuels and energy-demanding products.

A new climate scenario project

In 2011 a new climate scenario project (duration 2011-2014) is launched to address the following question: what are the effects of increased harvest (up to 50 % increase) upon carbon sequestration, biomass output for bio-energy and other uses, biodiversity and economy. The project is carried out by an interdisciplinary research consortium with a strong end-user group from environmental and forestry governmental institutions as well as the private forestry sector.

The primary objective is to develop a new forest carbon modelling framework and make integrated scenarios for carbon sequestration under different harvest levels plus effects on economics, biodiversity and geophysical climate impact. More specifically, the project will:

1) develop a new and flexible modelling framework for national scenario analysis
2) make updated growth and mortality functions
3) develop new functions to predict heartrot in live trees
4) parameterize the soil carbon model Yasso 07 for Norwegian conditions
5) analyse effects of silvicultural treatments on carbon dynamics
6) analyse biodiversity effects of different harvest levels
7) analyse economic impact of different harvest levels
8) arrange workshops to establish scenarios of interest for intended end-users
9) make short term- (20 years) and long-term (100+ years) scenarios under different forest management regimes (harvest level) and
10) evaluate global, long-term climate impacts (geochemical, geophysical) of different harvest levels.

The project aims to create a common understanding of trade-offs related to increased forest biomass extraction and it shall improve the knowledge basis for sustainable forest policies and resource management as well as strengthen the relationship between industry, government agencies and research institutions.

INFLUENCE OF GROWTH PERIOD TEMPERATURE ON ANNUAL RING CHARACTERISTICS IN BOREAL SCOTS PINE

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In boreal forests growth is to a large extent limited by the low temperature and temperature variations between and within growing season is therefore reflected in growth characteristics such as growth ring widths, proportions of early and late wood and wood density characteristics [2,3]. Ring width in conifers is basically a function of cell numbers and the radial dimension of the cells and wood density depends largely on secondary growth in the cell wall. The aim of the present study was to quantify the effect of temperature during the growing season on number of formed tracheids in early and latewood, and the wood density of early and late wood.

Four, dominating or co-dominating, Scots pine (*Pinus sylvestris* L.) trees were sampled from a mature pine stand in Northern Sweden (64º14'N, 19º47'E, 175 a.s.l.). Stem discs were taken from 1.3 m and 4 m of tree height and ring widths in the four cardinal directions were analyzed. Wood samples for tracheid measurements were prepared using 40µm thin sections in a sledge microtome. Digital images were then taken, 200 x 200 µm for early wood and 100 x 100 µm for latewood, using a light microscope and analyzed with respect to number and radial dimension of early and late wood tracheids. Based on basal area annual increment and the number of tracheids counted in the quadrants, total number of tracheids per m^2 was calculated for early and late wood. From the stem discs, wood samples of 2.3 mm thickness were prepared for microdensitometry analyses and analyzed using a direct scanning instrument with a 25 µm x 25 µm resolution (Itrax Wood scanner, Cox Analytical Instruments, Sweden) [1]. For each growth ring, cell number, density, late wood proportion, and densities of early wood and late wood were measured and correlated to weather data that was collected from a weather station less than 100 m from the sample trees. Shoot elongation was assumed to end July 1 each year and temperature sum during and after shoot elongation was calculated based on that assumption.

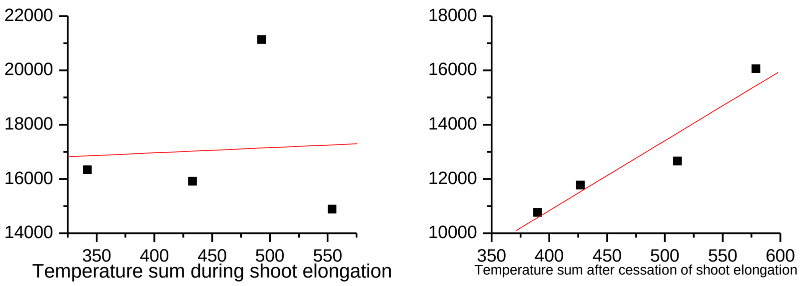

Figure 1. Number of cells formed per growth ring. Earlywood cells (a) during shoot elongation, latewood cells (b) after cessation of shoot elongation. Each quadrant represents

Number of early wood tracheids per growth ring was not correlated with variations in temperature sum during shoot elongation, whereas the temperature sum after cessation of shoot elongation showed a strong positive correlation (Fig. 1). Late wood density also showed a positive correlation with temperature sum after cessation of shoot elongation (Fig. 2). The results also showed differences between trees and effects of cardinal direction on early and late wood widths, number of tracheids in early and late wood, and late wood density.

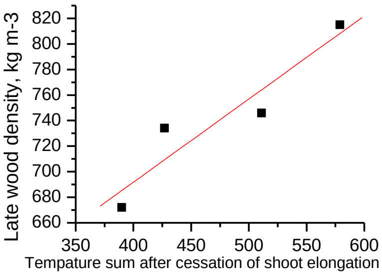

Figure 2. Relation between late wood density and temperature sum after cessation of shoot elongation.

The positive relation between number of late wood tracheids and temperature sum during late wood formation is in accordance with the theory of the temperature effect on xylem growth [3] and positive relation between temperature and numbers of formed tracheids has also been found for other species in the boreal zone [2, 4]. On the other hand, the lack of correlation between number of early wood tracheids and temperature sum during shoot elongation indicates that there are other factors affecting this process, such as frost events. In conclusion, increased knowledge on the relation between wood formation and weather factors provides vital information on how different climate change scenarios may affect xylem growth and differentiation and wood properties [5].

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COST-EFFECTIVE REGENERATION BY AVOIDING UNNECESSARY EARLY STAND MANAGEMENT COSTS

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Work productivity and the methods of young stand management have been almost unaltered for decades. Unlike commercial harvestings, which have gone through a massive change due to technological development, effective high-tech machinery for early stand management has proved difficult to develop. Selective harvesting or removing small stems with an expensive machine is costly. However, reducing costs of early stand management with an effective chain of regeneration operations seems to be a prominent method [1].

About 8-years old disc-trenched Norway spruce plantation suffers from hardwood invasion. (Metla/Erkki Oksanen)

Methods

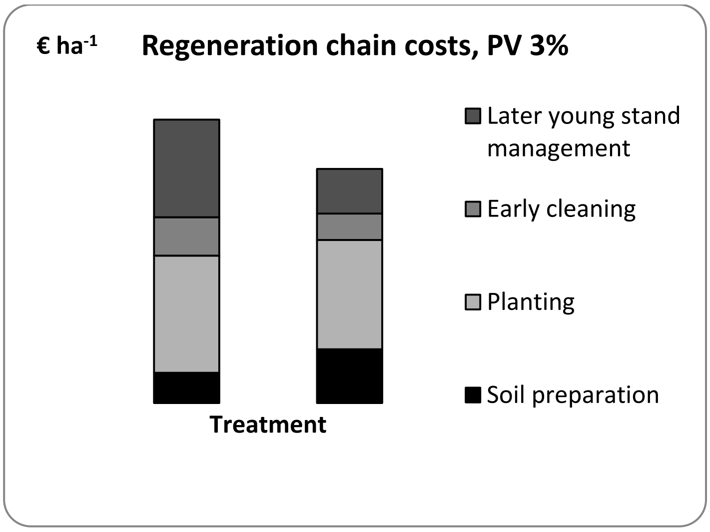
Economic result of forest regeneration chains, based either on spot mounding (SM) or on disc trenching (DT) and planting of Norway spruce (*Picea abies* [L.] Karst.) were compared. Effects of the methods were measured from field experiment. Then, by simulating stand level management programs, economic profitability of the methods was determined.

Results

Right decision in choosing a soil preparation method can lead to great savings when considering the total silvicultural management costs to the first commercial thinning. Young stand management costs often took a large share of the costs related to reforestation. Good regeneration operations increase growth of the valuable trees and minimize number and growth of the unnecessary trees, which also minimize the expected costs of young stand management.

In comparison of SM and DT, at biological age of 8 years, the mean heights of spruce plantations were 110 cm and 68 cm, respectively on SM and DT treatments. The density of the removed trees in early cleaning was 56 % higher on DT treatment compared to that of SM.

Although DT is a less expensive method than SM, the total management costs of the regeneration chain were higher in DT than in SM. Furthermore, incomes from the first commercial thinning were higher when regeneration based on SM.



Present values of the costs of the regeneration chains treated by DT or SM.

Conclusions

There are strong economic relations between soil preparation and later young stand management operations in boreal Norway spruce stands. Depending on discount rate and a soil preparation method, costs of the other operations in a regeneration chain might be 4–10 times higher than the soil preparation cost. Therefore, it is important to place extra attention to the costs of the whole regeneration chain when selecting a soil preparation method.

In addition, aiming at appropriate stand density as soon as possible is important in cost-effective regeneration. In energy wood harvesting, thinnest stems in over dense stands are very expensive to harvest, but profitable energy wood harvesting would require dense enough stands to produce appropriate amount of biomass ha^{-1} [2]. On the other hand, removing the surplus trees without harvesting is also expensive, if cleaning or pre-commercial thinning has been delayed.

Need, timing and costs of early stand management operations in more detail has been under research, but is still unpublished. Based on field experiment, early cleaning of 6–7 years old Norway spruce plantation clearly improved development of the crop trees. Based on extensive inventory data, predicting of early stand management according to basic site characteristics seems difficult.

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